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A Roentgenographic Study of the Orthodontic Movements Exhibited by the Mandibular First Molar Teeth During Class Ii Forces Utilizing Edgewise Mechanics and Light Wire Mechanics

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A ROENTGENOGRAPHIC STUDY OF THE ORTHODONTIC
MOVEMENTS EXHIBITED BY THE MANDIBULAR FIRST
MOLAR TEETH DURING CLASS II FORCES
UTILIZING EDGEWISE MECHANICS AND
LIGHT WIRE MECHANICS

by

Robert E. Krvavica

A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Master of Science

June

1963

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"Patience is a tree whose root is bitter, but the fruit is very sweet"

One can wait a long time for the right combination of events and persons to produce a "fiat accompli."

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CHAPTER I

INTRODUCTION

A. Introductory remarks

Studies by Sandstedt (1904), Oppenheim (1944), Schwarz (1932), on the biologic and histologic activities of cells and tissues in areas affected by orthodontic forces have shown that orthodontic tooth movement depends upon bone resorption and bone formation, which in turn is affected by the amount of force employed. Sandstedt (1904) said that a heavy orthodontic force causes the cellular activity to be greatly inhibited in the immediate vicinity of the force. The resulting necrotic bone must then be removed before the tooth will move in the direction of the force. This is the phenomenon of undermining resorption. Schwarz (1932) said that orthodontic tooth movement will cause the width of the periodontal membrane to be decreased on the side of pressure and increased on the side of tension.

B. Statement of the problem

The present study was designed to appraise and analyze the radiographic changes in the periodontal space and crib-form plate surrounding the mandibular molar teeth in patients undergoing Class II force applications during orthodontic treatment, and to determine the amount and direction of tooth movement

taking place. It is a continuation of studies started by Gantt (1960) and continued by Kemp (1961) on patients treated with light differential forces, and Stier (1962) on patients treated with edgewise mechanics.

A roentgenographic survey was employed to determine the bone resorption and apposition in the mesial, distal, and apical regions. Because roentgenograms are only two dimensional, buccal and lingual tipping movements, or small axial rotations, will not be shown on these roentgenograms, nor can the exact distance of tooth movement be determined. It is believed that this method will accurately show those areas of tissue activity by the changes in the periodontal space and cribriform plate which demonstrate the direction and type of tooth movement taking place at a precise time.

A correlation is also made with cephalometric roentgenograms to appraise the type and amount of tooth movement which occurred and to establish the point of rotation in cases of tipping movements. This method is subject to certain error factor because of the difficulty of visualization of the teeth on the lateral cephalometric headplate; however, the experimental uncertainty is taken into consideration in the statistical analysis.

CHAPTER II

REVIEW OF THE LITERATURE

Sandstedt was the first investigator (1904-1905) to use histological techniques to examine orthodontic tooth movement. He performed a series of experiments on one year old dogs which consisted of tipping the six maxillary incisor teeth lingually by means of threaded labial arch wires, tightened with nuts every day for three weeks.

Sandstedt showed that using light or heavy forces, new bone is deposited on the old alveolar wall. This occurred on the labial or tension side. The new bone is laid in the direction of the applied force and could easily be distinguished from the old alveolar bone. Areas of resorption in the alveolar bone were evident on the lingual or pressure side in those cases where a light force had been applied. The surface of the tooth root was not affected. With strong forces, the results differed in that the soft periodontal tissues were compressed to such a degree that a loss of vitality occurred and bone resorption did not take place at this site. There was evidence of resorption in the adjacent marrow spaces proceeding toward the area of pressure and removing the necrotic tissues. When all the necrotic tissue is removed, the tooth rapidly assumes a new position. Sandstedt

called this phenomenon "undermining resorption." He also concluded that teeth were tipped from a fulcrum located about the middle one-third of the root.

Another series of experiments were conducted by Oppenheim (1911-1928) on animals and later on humans. Teeth were subjected to light, medium, and heavy orthodontic forces over a period of five to forty days. Tipping, extrusion, intrusion, and rotational movements were performed, along with control specimens.

Oppenheim's findings did not coincide with those of Sandstedt. Oppenheim thought there was a difference in the reactions occurring in the compact cortical layer of the alveolar bone and those taking place in the spongy intermediate bone. He maintained that the lamellae of the compact alveolar bone was transformed under light forces into a transitional spongiosa by the influence of pressure and pull on both sides of the moved teeth which was oriented in the direction of the applied force.

He noted that the tooth movement took place by tilting around an axis at the apex of the tooth; therefore, there is only one side of pressure and one side of pull. On both sides, the transitional spongiosa is formed and arranged vertically to the surface of the tooth. On the side of pressure, this newly formed transitional bone is resorbed; on the side of pull, new bone is added.

Oppenheim concluded that light forces applied over a long period of time were the best form of orthodontic treatment. His observations were that there was damage to bone no matter how light the artificial force. When strong forces were used, the normal reaction of bone was lacking due to tearing of the periodontal fibers and thrombosis. The forces used in the experiments by Sandstedt and Oppenheim were classified subjectively as light, medium, or heavy. They made no effort to measure their magnitude.

Johnson, Appleton and Rittershofer (1925) conducted experiments on Macaque Rhesus monkeys. They described the movement of the incisor labially as a tipping action and showed that the apex moved in an opposite direction (lingually) while the crown moved labially. They discovered that one or two ounces of pressure was sufficient to move these teeth.

Schwarz (1932) measured forces using an auxiliary spring appliance and measured the forces resulting from the various parts of the spring. He concluded that biologically the most favorable treatment is that which works with "forces not greater than capillary blood pressure, about 23 grams per square centimeter." Schwarz also emphasized the fact that in a tipping movement the force varies at different root levels, being greatest near the alveolar crest and at the apex, and decreasing gradually until it is zero at the tilt axis. As a consequence, the tissue reaction must vary proportionately.

According to Gottlieb and Orban (1931), the physiologic width of the periodontal membrane was that width attained while the tooth was in function. The biologic width was that of the periodontal membrane when the tooth was not in function. The physiologic width was found to be greater than the biologic width. The resorption of the adjacent bone takes place when the pressure applied to the tooth causes the width of the periodontal membrane to become less than the biologic width. The fibers of the ligament transmit any force applied to the crown of the tooth to the supporting bone. The nature and intensity of tissue reactions to orthodontic forces is therefore determined by the condition of the periodontal ligament.

Kellner (1928) reported cementum as thin in functioning teeth, thick in non-functioning teeth, periodontal membrane wider in functioning teeth, narrower in non-functioning teeth.

Klein (1928) found periodontal widths vary with age and root levels. Average width for the ages between 20 and 25 was 0.23 mm, 0.28 mm for teeth in heavy function, 0.20 mm for teeth not in function.

Coolidge (1937) concurred with earlier findings on the width of the periodontal membrane. He also observed that the periodontal membrane of a drifting tooth was considerably wider on the tension side than on the pressure side and varied with in-

dividuals, teeth and different areas of the same tooth.

Kronfield (1931) showed that the periodontal membrane not only varies with function but also with age, being wider in young.

The periodontal membrane is involved in bone alterations in two ways: (1) periodontal fibers transmit forces from tooth to alveolar bone, (2) bone forming and destroying cellular elements are often to be found in the periodontal membrane. The factors which have an effect on this process of change in the periodontal membrane and bone when an activated orthodontic appliance is placed are: (a) the amount of force in grams or ounces, (b) the distance the force is active, and (c) the length of time the force is applied.

Regardless of how movement might be classified, the periodontal membrane reacts biologically as stated above.

Huettner and Whitman (1958) in their experiments with Macaque Rhesus monkeys using the edgewise technique found that in every one of the animals used there was always a distal movement of the anterior segment, and at the same time, there was a mesial movement of the posterior segments which were used for resistance.

They found histologically that "tip-back" bends were the most damaging orthodontic movement and that torquing was the second most damaging. The so-called "tip-back" bends did not

prevent mesial movement of the posterior segments but did produce the most severe root resorption. They also found that tipping the molar teeth in a distal axial inclination did not enhance their resistance to forward movement.

Stuteville (1938) found root resorption in all cases in which the force was active through a greater distance than the width of the periodontal membrane involved. He states: "It is not so much the amount of force that produces root resorption as it is the distance through which the force is active."

Storey and Smith (1952) used the edgewise mechanism for experiments with auxiliary spring forces of varying values to move canines distally. First permanent molars, together with second premolars, were used as anchorage for the springs to move canines distally into the first premolar extraction spaces.

They found an optimum range of force values that should be used to produce a maximum rate of movement of the canine; this is 150-200 grams. The maximum rate of mesial movement of the molar anchor unit occurred in the high range of force values, 300-500 grams. When the force was below 300 grams for the molar anchor unit, neither tooth moved appreciably.

Halderson, Johns, and Moyers (1953) found that a force of over two pounds is exerted by an edgewise wire. They also found that using a series of light round wires in starting edgewise mechanics takes advantage of tipping movements and uses

forces much lighter than possible with a standard edgewise wire.

Jarabak (1960) gave tangible values to the terms "light forces" and "excessive forces." Heretofore, these terms were used without ever having any scientific connotation as the subjective evaluation of a force by different operators varies to a great extent.

Orthodontic forces beyond 6-7 ounces have been shown to be excessive and result in a decreased rate of tooth movement. (Storey and Smith, 1952; Begg, 1954; Reitan, 1957; and Jarabak, 1960.) A light orthodontic force ranges from about 1-4 ounces (30-120 grams), an intermediate force from about 5-6 ounces (140-160 grams).

Reitan (1957) showed that one of the first signs of orthodontic forces exceeding 200 grams is that of the lack of cellular activity which is later followed by hyalinization in the periodontal ligament.

Stuteville (1937-1938), Sicher and Weinman (1953), Reitan (1951-1956), Wentz, Jarabak, and Orban (1958), have all shown that the physiology of the periodontium and the cellular activity of the periodontal bone itself are affected in different ways depending on the type of orthodontic forces used and the degree of these forces used to control the movement of the teeth.

Jarabak (1959) has stated:

The picture of the bone activity which occurs in the areas which surround teeth moved orthodontically can

be attributed, in general, to the degree of stimulation of the normal physiology of the periodontium. This degree of stimulation of the normal periodontal physiology is affected by the intensity, magnitude, and duration of the forces used to control the movement of the teeth.

Wentz, Jarabak, and Orban (1958) in their experiment on monkeys created tooth jiggling by producing forces of traumatic occlusion (imitating cuspal interference in a buccolingual direction). The histologic sections showed enlarged periodontal membrane around the involved teeth, containing hyalinized connective tissue. As the jiggling movement continued, a cycle of crushing, undermining resorption and repair took place in the periodontal structures. There was no definite pressure or tension side, but rather the combined effects of both pressure and tension were recorded as the tooth was jiggled buccally and lingually. The periodontal membrane became increasingly wide until it was more than three times the original width, resulting in extreme mobility of the involved tooth.

Among the diagnostic and treatment aids, the roentgen-ray has long been used in the study of normal and pathologic conditions. Soon after their discovery in 1895, x-rays became an indispensable tool in medicine and dentistry, both in practice and research.

Although intra-oral roentgenograms are used routinely in dentistry for periodic caries check-ups and examinations, it is quite uncommon for the orthodontist to take or ever

refer to intra-oral roentgenograms once orthodontic treatment has begun. This is unfortunate because the orthodontist is overlooking a fine indication of treatment progress in the intra-oral radiograph. (Jarabak 1960.)

Teleroentgenography, as discussed briefly by Schwarz (1957), is a comparatively new technique which unfortunately is hardly used in dentistry. In teleroentgenography, the roentgen-ray tube is placed at a distance of about six feet from the film to obtain parallelism of rays, thus avoiding distortion. The roentgenographic appearance of the cribriform plate has been repeatedly described as an "even thin white line surrounding the tooth root." This description does not fit every tooth. (Updegrave 1958.)

Massler (1954) said the thickness and degree of radiopacity of the cribriform plate in x-rays indicate the area and amount of new bone formation, and therefore the direction and amount of tooth movement.

Gantt (1960), Kemp (1961), and Stier (1962) employed teleroentgenograms in their studies of the movement of the mandibular first molars serving as anchor units during orthodontic treatment. An appraisal was made based on the dimensional changes in the periodontal space and lamina dura as shown on intra-oral roentgenograms. Gantt and Kemp found that during anchorage preparation utilizing the Loyola University Light Wire

Technique, the most prevalent movement of the anchor teeth was simultaneous extrusion and a distal tipping, the tilt axis being located near the apex or middle one-third of the distal root. As a result of this axial change, the mesial root elevated.

Stier, employing Tweed Edgewise Mechanics, found that the predominant tooth movement of the mandibular first molars during the stage of anchorage preparation (utilizing tip-back bends in conjunction with "X" type orthospec class III elastics) was a distal tipping movement in which the average mesial root movements was greater than the distal crown movement. The axis of rotation for this distal tipping movement was located in the majority of cases within the cervical one-third of the root above the midpoint of the root.

Jarabak (1960) has shown by means of intra-oral roentgenograms that with light-wire mechanics, mandibular molars upright about a fulcrum somewhere near the apices of the distal roots, and the premolars tip distally about a fulcrum in the lower third of the roots at the same time. Intra-oral roentgenographic evidence was also presented showing that resorption and apposition of bone approximated physiological balance when the differential force technique was employed because the periodontal space remained small during treatment indicating an equal rate of apposition and resorption. Very little or no root resorption occurred during treatment as evidenced by the x-ray study.

CHAPTER III

MATERIALS AND METHODS

A. Materials

Two groups of children undergoing orthodontic therapy at the Loyola University School of Dentistry comprised the sample for this study.

Group 1. Patients Treated with Loyola Differential Forces Technique

Fourteen children, seven females and seven males, were used in this study. Seven cases required the removal of teeth due to excessive discrepancy between tooth material and apical base. Seven cases were treated non-extraction. The distribution of material is presented in Table I.

All subjects were treated by the graduate students in the Orthodontic Department of the Loyola University School of Dentistry, utilizing the principles of the light wire technique.

In previous studies these same patients were used for:

(1) the evaluation of tooth movements during stages of mandibular anchorage preparation (a clinical term meaning the uprighting of the mandibular molar and premolar teeth), (Gantt 1960);

(2) during the space consolidation (closure of spaces), (Kemp 1961).

This study involving Group 1 is the completion of the research problem and is concerned with tooth movements from the stage of space consolidation to the end of treatment.

Group 2. Patients treated with edgewise technique

Eleven children, seven females and four males, were selected for this investigation. Eight cases required extraction of four first bicusps. Three cases were treated non-extraction. The distribution of the subjects by age is presented in Table II.

In a previous study, Stier 1962, used these same patients to determine tooth movements in mandibular molar teeth during stages of separation, leveling, and anchorage preparation.

All subjects were treated by the graduate students in the Orthodontic Department of the Loyola University School of Dentistry, utilizing the principles of Tweed Edgewise Mechanics.

The study involving Group 2 is a continuation of the original problem and is concerned with tooth movements during stages of Class II forces (forces exerting a mesial component of force on mandibular molar teeth).

B. Methods of study

The methods used to obtain the data for this investigation were from two sources, lateral cephalometric head-

plates and intra-oral roentgenograms of the mandibular first molars, using the Universal Cephalometrix apparatus. (Figure 1.) The fixed distance between the Universal cephalostat (head-holder) and the focal point of the roentgen tube was sixty inches for lateral headplates.

A headspanner for orientation of the head, constructed by F. W. Steiner of Chicago, Illinois, was adapted (Gantt) and attached to the crossbar of the Universal cephalometric apparatus in a position thirty inches from the focal point of the roentgen ray tube. (Figure 2.) This distance was one half the fixed distance (sixty inches) from the focal point of the roentgen ray tube to the Universal cephalometer. This reduction of target distance permitted a reduction of exposure time while still taking advantage of the central ray in order to minimize the enlargement factor. The use of a headspanner was necessary in order to prevent distortion errors due to movements of the subject's head, and to allow the operator to replace the subject into the headspanner in the same spatial relation to the roentgen-ray tube each successive time a record was taken.

An adapter (Figure 3) was constructed to attach the headspanner to the transverse bar of the Universal apparatus. This adapter consisted of the following parts: (1) a vertical arm which was attached to the horizontal transverse bar of the Universal cephalometric apparatus; (2) a horizontal arm with a

TABLE I
 DISTRIBUTION OF THE SUBJECTS BY AGE
 LIGHT-WIRE TECHNIQUE

Age (Years)	Total
11	1
12	3
13	5
14	3
<u>15</u>	<u>2</u>
Mean 13.92	Total 14

TABLE II
DISTRIBUTION OF THE SUBJECTS BY AGE
EDGEWISE TECHNIQUE

Age (Years)	Total
12	1
13	2
14	3
15	4
<u>17</u>	<u>1</u>
Mean 14.27	Total 11

sleeve which fit over the vertical arm of the adapter and was attached to it at a right angle. The headspanner also had a sleeve which fit over the horizontal arm of the adapter. These two sleeves were secured in a position by large thumb screws which allowed the arms to be fully adjustable. The sleeves were drilled and tapped and outfitted with set screws and lock nuts which gave the sleeves a very close tolerance fit.

1. Alignment of ear-rods and calibration of the adapter arms

The two ear-rods of the headspanner were slotted and marked with lead indicators in their respective centers, thus providing an index by which they could be aligned with the central ray. A series of trial-and-error adjustments were made until the centers of the two ear-posts were in direct alignment as shown by the exact super-position of the two lead indicators on a roentgenogram (Figure 4). This position was then defined as "zero" and suitable reference lines were marked on the horizontal and vertical adapter arms. Millimeter scales were fastened to both horizontal and vertical arms in such a manner that the zero points of the millimeter scales coincided with the reference markings on the adapter arms. The continued accuracy of the ear-post alignment was checked each time before taking a new series of data on each subject.

2. Alignment of mandibular first molar area with the central ray

From each of the lateral head-plates taken before

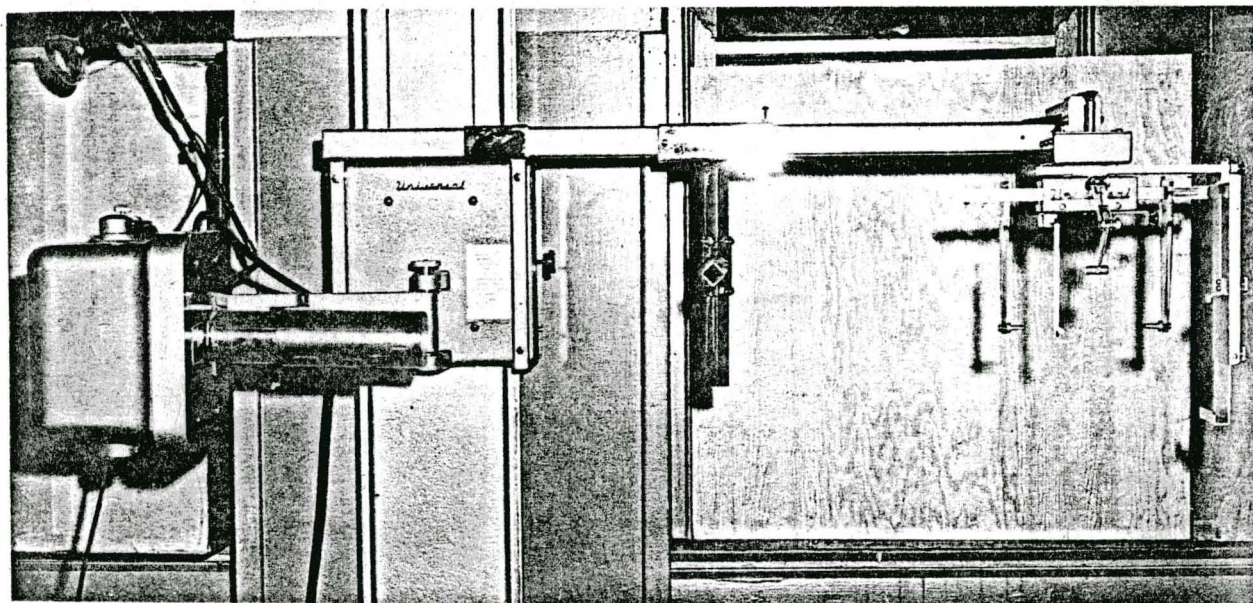


FIGURE 1

THE UNIVERSAL CEPHALOMETRIX UNIT

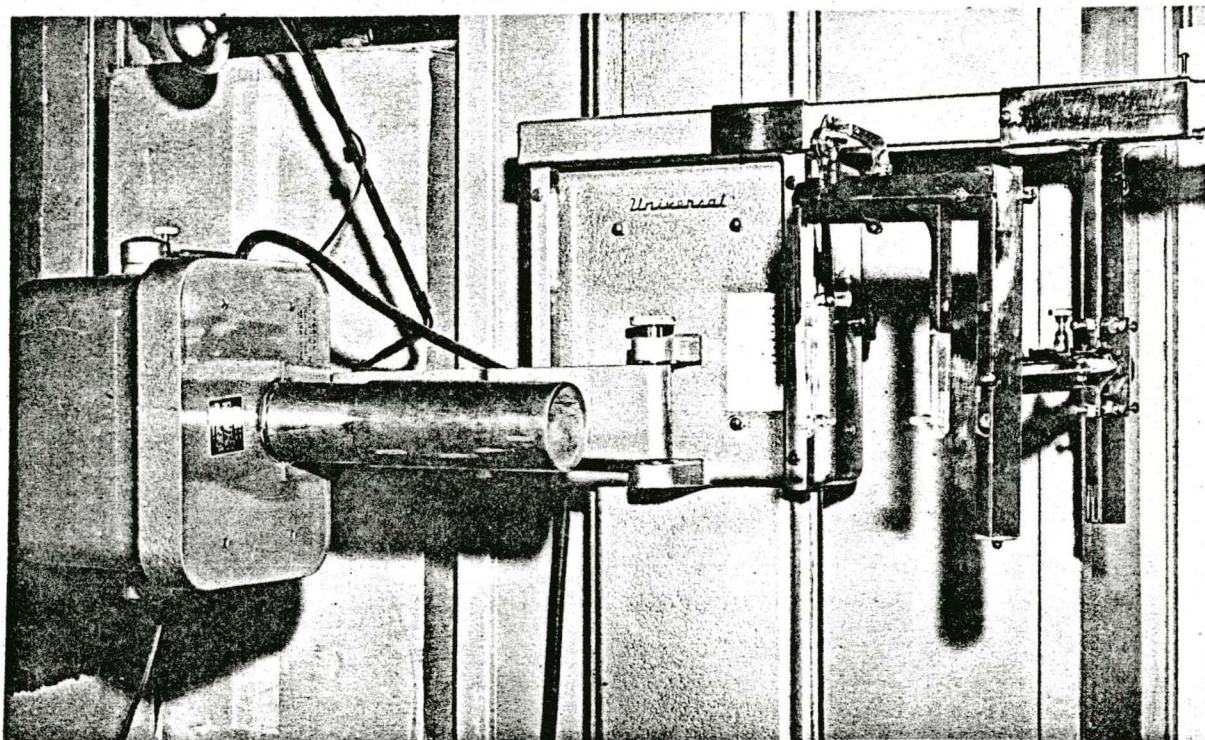


FIGURE 2

THE HEADSPANNER MOUNTED ON
THE UNIVERSAL CEPHALOMETER

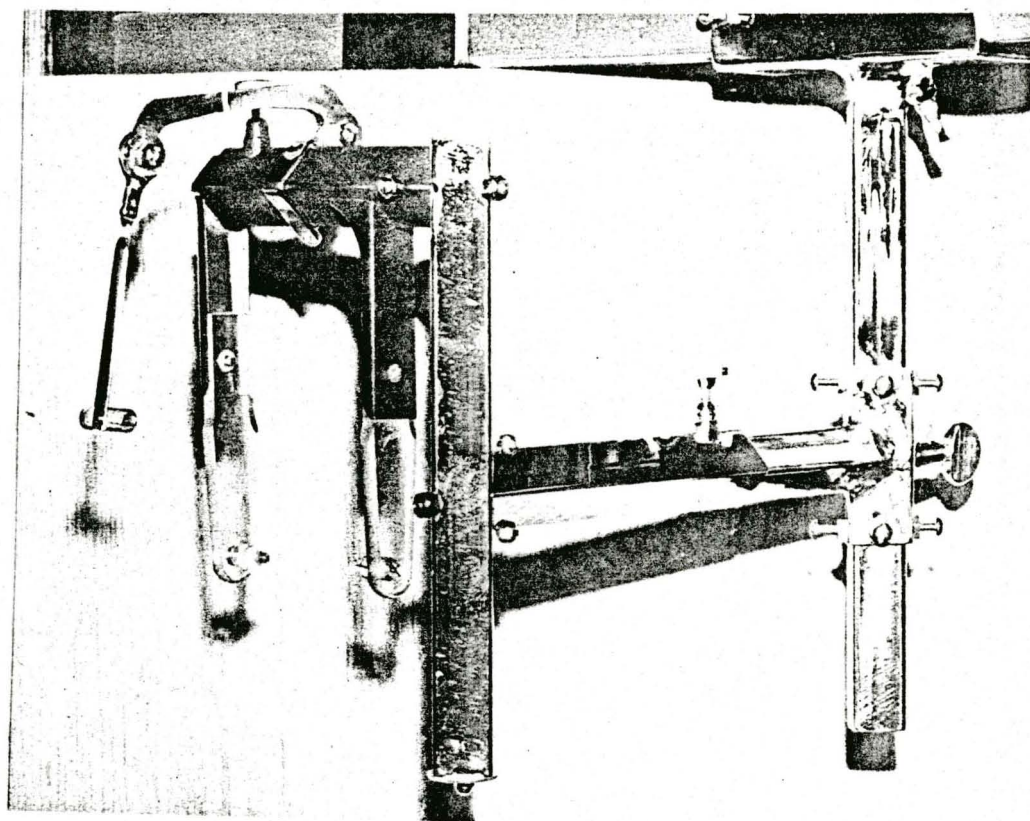


FIGURE 3

HEADSPANNER WITH VERTICAL
AND HORIZONTAL ADAPTER ARMS

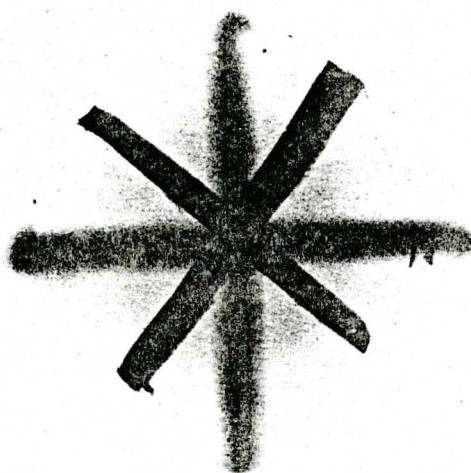


FIGURE 4

SUPERIMPOSED LEAD INDICATOR SHOWING
THE ALIGNMENT OF THE EAR-POSTS WITH
THE CENTRAL RAY

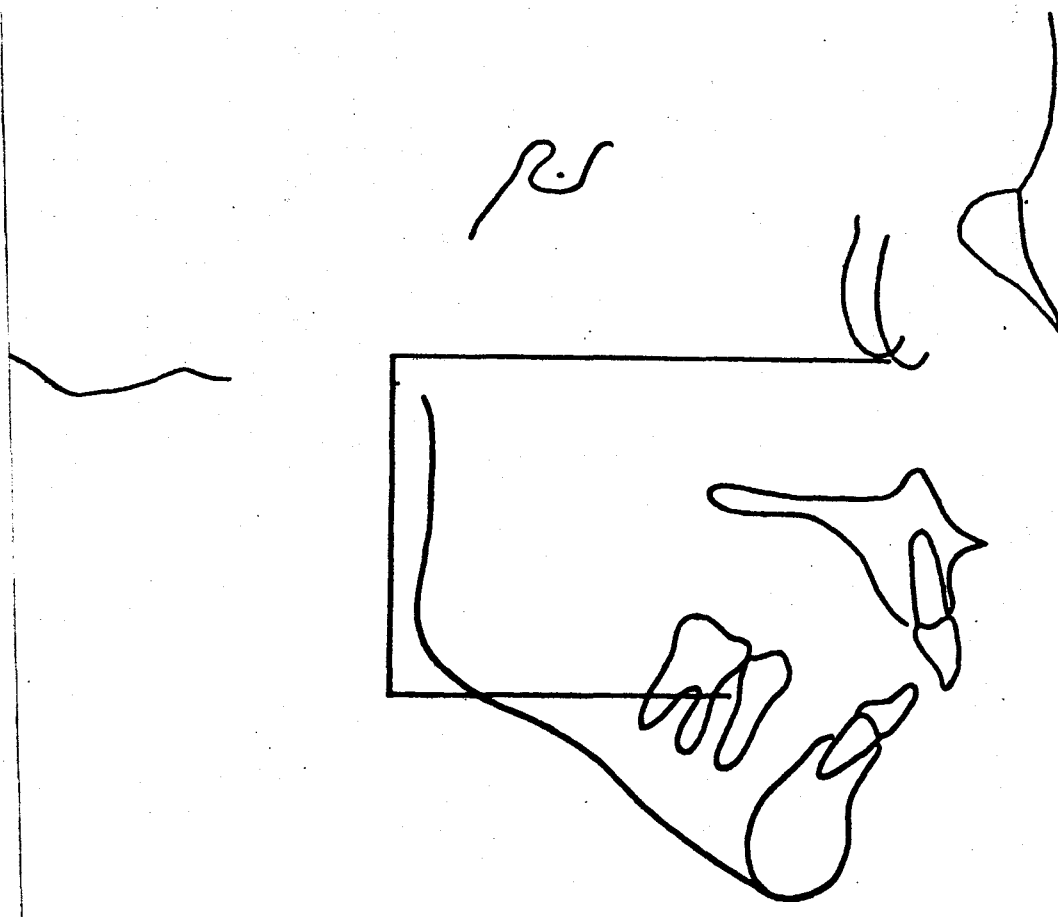


FIGURE 5

TRACING OF A LATERAL HEADPLATE
INCLUDING THE X AND Y COORDINATES

intensifying screens which served to reduce secondary radiation and to provide greater contrast on the x-ray. The machine setting for each exposure was 87 KVP and 25 MA with an exposure time of one-half second. The film used for the intro-oral records was DuPont code D-2, double coated dental x-ray film. The machine setting was the same as above with an exposure time of two and one-half seconds for each film.

C. Measurements

The subjects were placed in the head positioner after it had been adjusted to the previously established measurements for each individual. Two intra-oral roentgenograms were then taken of both the right and left mandibular first molar areas prior to treatment. These films were the first series and were marked I A and I B (patient's right side), and I C and I D (patient's left side). Subsequent series were marked with the patient's number and the series number in accordance with the above technique. The replications were taken to provide a measure of experimental error.

After uniform processing, keeping the developing time, temperature and concentration of the solutions constant, the roentgenograms of the first series were transilluminated on a tracing table. Under a stationary three power magnifying lens, the root images of the mandibular first molars were marked in four areas in the following manner: with a fine pointed needle,

the film was perforated in the marginal area of the mesial root about one millimeter from the periodontal space where the latter was best distinguishable. This marking was designated as "point A." The same procedure was followed in marking point B (apical area of mesial surface of mesial root), point C (marginal area of distal root), and point D (apical area of distal surface of distal root). (Figure 6.)

Each film of the first series thus marked was then superimposed individually over each of its follow-up films in subsequent series in order to transfer the perforation marks to the same areas. Thus, the comparison of the periodontal space around each tooth was made very nearly at the same level in each successive series. After all roentgenograms were marked and bound as slides, they were projected on to a white cardboard screen at a fixed distance of eight feet from the lens, which distance was maintained throughout the observation period. A magnification factor of 20:1 was established and re-checked by projecting a slide of a metric scale in such a manner that a distance of two millimeters on the slide measured forty millimeters on the screen.

The slide projector used was a Kodak Cavalcade with a Kodak Ektanar Projection Lens, 5 inch, F 12.8 (courtesy of Dr. J. R. Jarabak).

The changes in width of the periodontal space and

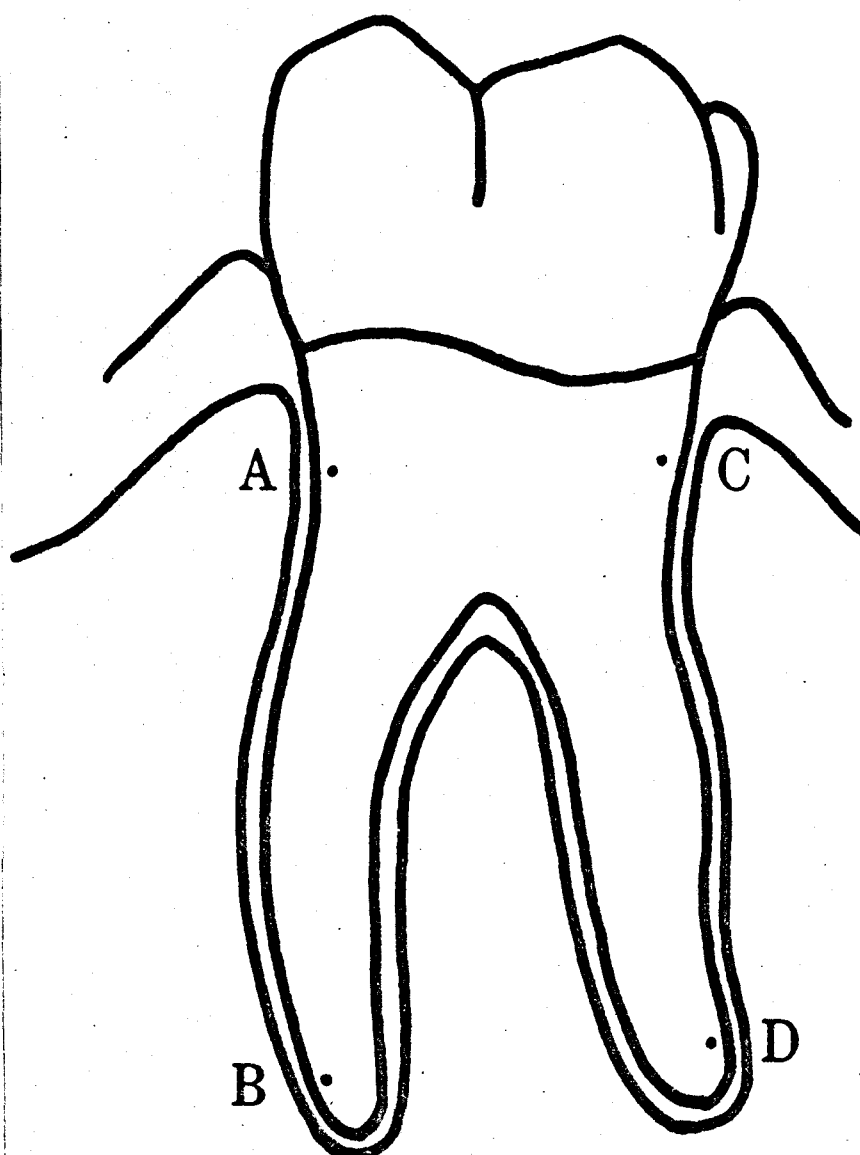


FIGURE 6

MARGINAL AND APICAL REFERENCE
POINTS A, B, C, AND D, AS MARKED
ON THE INTRA-ORAL ROENTGENOGRAMS

the types of tooth movements were appraised in the following manner. A reference strip of plain white paper, one inch wide and ten inches long, was divided lengthwise into four sections (A, B, C, D), each corresponding to one of the four areas marked on the roentgenograms as described previously. In each section, a thin vertical line was drawn and labelled as the reference line (Figure 7). The first slide, Series Number I A of patient Number 1, was then projected on to the screen and the white paper strip was placed against the screen in such a manner that the reference line in section A coincided with the image of the outer border of the cementum, adjacent to point A (marginal area of the mesial root). The width of the periodontal space was estimated for this area and recorded on the reference strip by drawing a short vertical line with a fine pointed red pencil. This procedure was repeated for points B, C, and D, recording each width on the respective section of the same reference strip (Figure 8). The next slide projected was that of the same tooth after the next stage of treatment to be studied had been recorded. Using the same reference strip, the same procedure for recording the periodontal widths in the four areas was followed, except this time, a fine pointed pencil of another color was used.

In the first method of evaluating the data, the paper strips which have just been described were employed to reveal the direction of change in the width of the periodontal

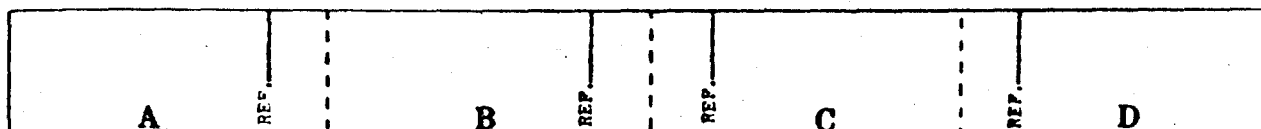


FIGURE 7

REFERENCE STRIP

EACH SECTION CONTAINS A REFERENCE LINE
CORRESPONDING TO ONE OF THE REFERENCE
POINTS A, B, C, D, WHICH WERE MARKED ON
THE INTRA-ORAL ROENTGENOGRAMS

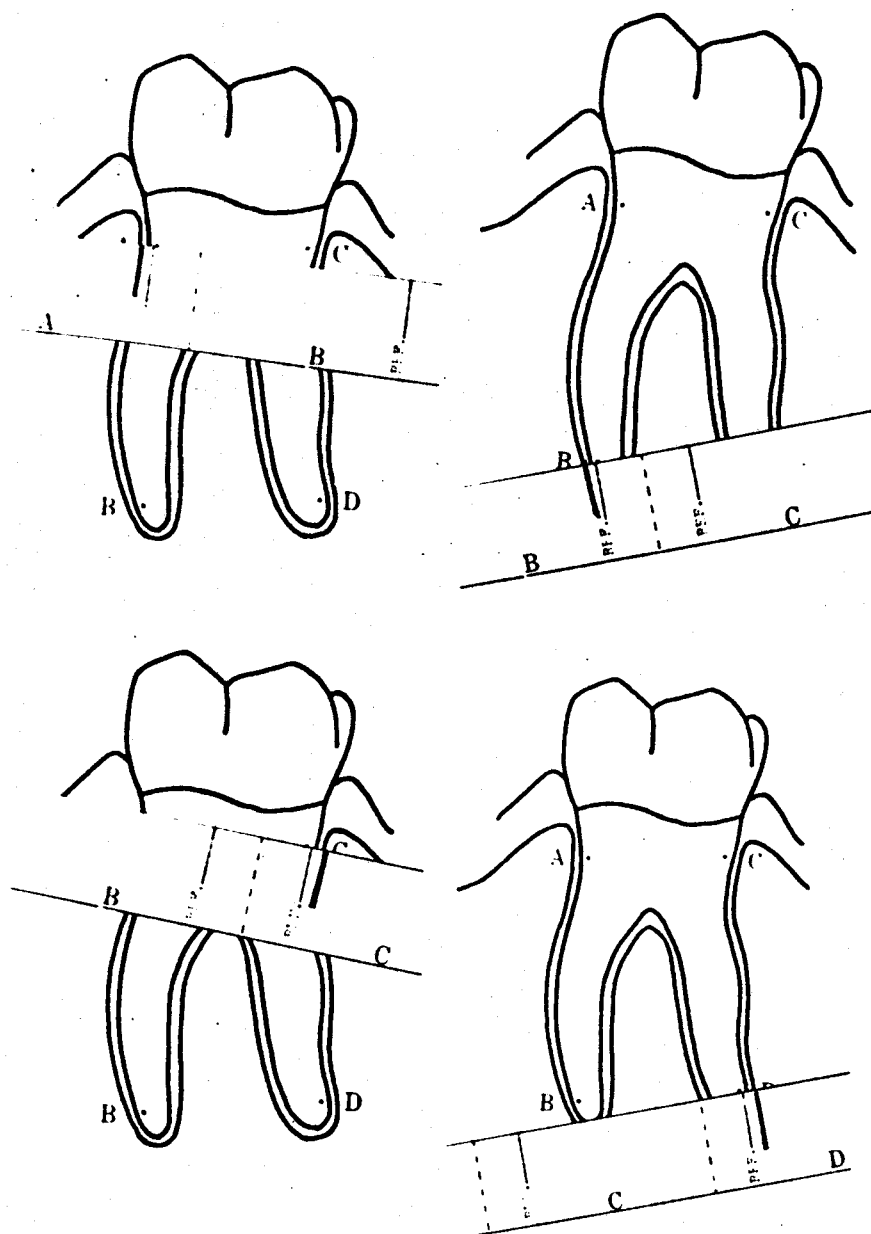


FIGURE 8

EVALUATION OF AREAS A, B,
C, D, PRIOR TO TREATMENT

space. A decrease was indicated if the second line fell between the first (red) line and the reference line. If the second line was recorded outside the red line, the space was evaluated as having increased. Correlation of the changes occurring at the four marked positions could then be made to reveal the type of tooth movement which took place in the interval being studied. This procedure was followed on each of the intra-oral x-ray films in each series.

The second method of evaluating these data was a visual, subjective appraisal. The original pre-treatment film and its follow-up series were all projected simultaneously, which made it possible to compare visually any particular stage of treatment with any other, and to obtain a composite picture of the type and direction of tooth movement. The findings from this visual appraisal were then interpreted and compared with those derived from the records on the reference strips.

The third method of evaluation required that measurements be made on cephalometric headplates taken after class II forces had been utilized for a period of twelve weeks in the edgewise treated patients in order to determine the amount of tooth movement which occurred during this treatment interval. This was then compared to headplates taken after anchorage preparation (Stier) to measure any changes brought about by the reversal of forces, i.e., from a class II force exerting a mesial component

of force on the mandibular molar teeth. In the case of light wire patients, comparisons were made between headplates taken after consolidation mechanics (Kemp 1961) and at the completion of treatment.

A tracing was made of each original headplate showing the mandibular symphysis, the inferior border of the body of the mandible, the angle at the junction between body and ramus, the posterior border of the ramus, and the right and left mandibular first molars. The mandibular plane was then established by drawing a straight line between menton (most inferior point of mandibular symphysis) and the most inferior point at the angle of the mandible. A reference line was drawn perpendicular to the mandibular plane and tangent to the inner border of the symphysis. Two reference points were marked on each of the mandibular first molars--point C in the area of the greatest convexity on the mesial outline of the crown, and point R at the apex of the mesial root. Straight lines parallel to the mandibular plane were traced from each reference point on the molars (point C and R) to the reference line tangent to the symphysis. The lines thus constructed are shown in Figure 9 as "c" and "r." The respective lengths of these lines were measured in millimeters and recorded in column "A" on a data sheet. The tracing was then superimposed on the follow-up headplate and the outline of the right and left mandibular first molars at this stage of treatment were drawn on

the same tracing in dotted lines. The same procedure was followed in measuring the distances c' and r' between the reference line and the tooth in its new position, and these distances were recorded in column "B" on the data sheet. The differences between the values in column A and column B were calculated and recorded in column C on the data sheet. These differences were marked with positive or negative signs depending on whether the difference represented an increase or decrease in the respective measurements. The data were analyzed statistically and transformed into graphs in order to evaluate the types of tooth movements which occurred.

The cephalometric landmarks described above were selected for the following reasons:

- (1) The inferior and posterior borders and the symphysis of the mandible were traced in order to facilitate an exact super-position of the tracings on the headplates.

- (2) The inner border of the mandibular symphysis was chosen as the reference landmark because its cephalometric relation to the mandibular first molar facilitated the measuring technique and it is easily identified on the lateral headplate.

- (3) The selection of the mandibular symphysis as a reference for the positions of the mandibular teeth was preferred to other cranial cephalometric landmarks because the relation between cranium and mandible may change during orthodontic treatment. Thus by establishing a reference on the mandible,

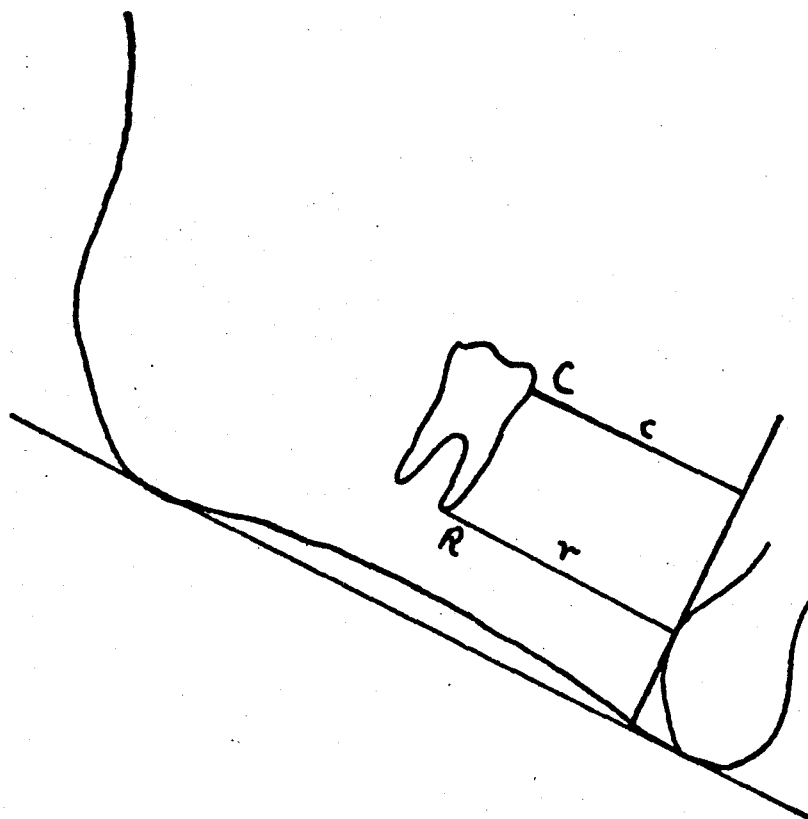


FIGURE 9

TRACING OF MANDIBULAR LANDMARKS FROM A
LATERAL HEADPLATE TAKEN BEFORE TREATMENT.
(c AND r REPRESENT THE DISTANCES OF THE
CROWN AND APEX FROM THE REFERENCE LINE
AT THE INNER BORDER OF THE SYMPHYSIS.)

the position of the mandible would not affect the validity of the measuring technique.

D. Design of orthodontic appliance

1. Loyola University light differential forces technique

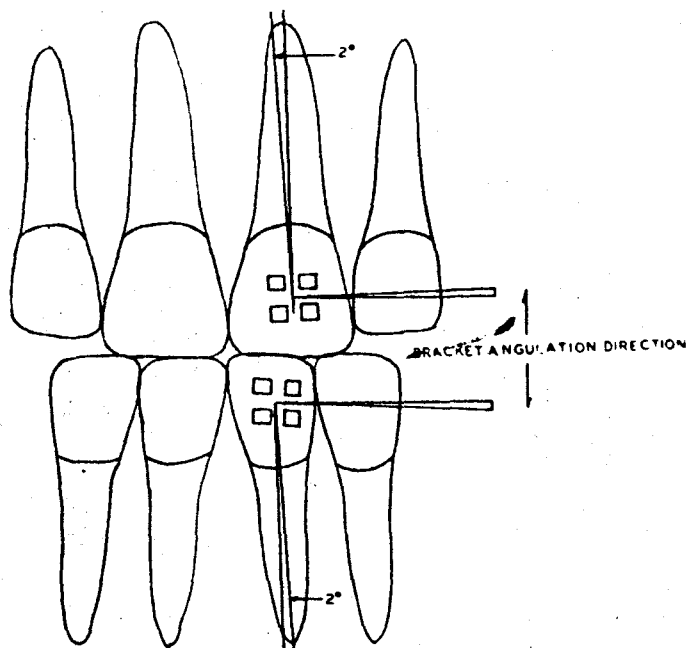
Each of the subjects was fully banded using angulated brackets on the bands. The brackets were angulated from the horizontal in order to give the teeth a distal angulation (tip-back) when a straight wire was fitted into the bracket boxes (Figure 10, courtesy of Dr. J. R. Jarabak).

Only those subjects were used who were treated with light, highly resilient, round arch wires. The entire group of fourteen subjects was treated employing initial arch wires of .016 inch diameter Elgiloy semi-spring wire. Prior to their insertion, all arch wires were tempered to spring hardness after having been first fashioned individually for each subject.

Nine of the subjects were treated with differential forces appliances placed in both maxillary and mandibular arches. Most of these subjects required extraction of the four first premolar teeth due to insufficient arch length. This type of arch wire employed bent-in vertical helical loops in the anterior segment of the arch; bent-in hooks located against the mesial surface of the canine brackets; and straight posterior segments extended distally through the buccal segments of the dental arch. These straight posterior segments were slightly curved in the

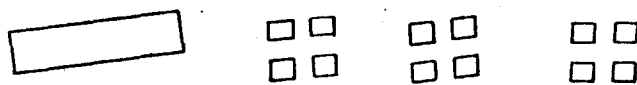
ARTISTIC ALIGNMENT
OF
ANTERIOR TEETH

36

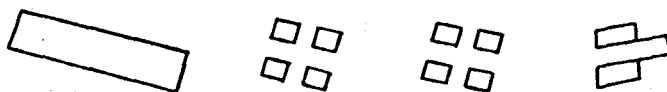


MESIO-DISTAL BRACKET ANGULATION

MAXILLA



OCCLUSAL PLANE



MANDIBLE

FIGURE 10

BRACKET ANGULATION FOR THE ANTERIOR
AND POSTERIOR PARTS OF THE MOUTH

horizontal plane of space to provide some arch form. (Figure 11 shows a typical helical loop arch.) These subjects were also required to wear rubber elastics. These elastics were made of latex rubber $1/4$ inch in diameter. They were of two types: (a) light $1/4$ inch elastics, which upon testing exerted an average pull of two ounces, and (b) heavy $1/4$ inch elastics which exerted an average pull of three to four ounces. These averages were obtained when the elastics were stretched a distance of about one and one-quarter inches, this being the average distance from the buccal tube of the mandibular first molar band to the hook on the arch wire mesial to the mandibular canine tooth.

These subjects wore the elastics in the following manner on each side of the mouth: (a) one $1/4$ inch light elastic worn from the end of the arch wire on the buccal surface of the first mandibular molar tooth to the bent-in hook located mesially to the mandibular canine bracket (intra-maxillary elastic); (b) one $1/4$ inch light elastic worn from a hook located on the lingual surface on the band on the mandibular first molar tooth to the bent-in hook located mesially to the maxillary canine bracket (oblique inter-maxillary elastic); (c) one $1/4$ inch heavy elastic worn buccally from the mandibular to the maxillary arch as a triangle having its base on the maxillary arch and its apex on the mandibular arch. This elastic worn in a "triangular" fashion was attached from the end of the maxillary arch wire on the first

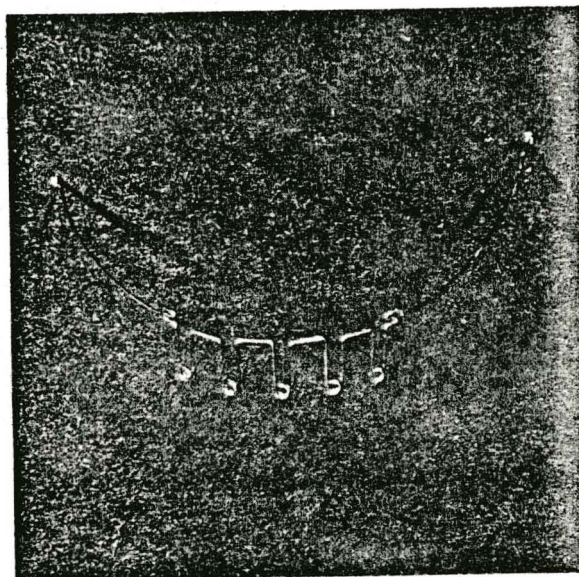


FIGURE 11

A TYPICAL HELICAL TORSION LOOP ARCH
WIRE FOR DIFFERENTIAL FORCES APPLIANCE

molar to a ligature wire hook (pigtail) on the maxillary second premolar tooth and then down to a similar ligature wire hook on the mandibular second premolar tooth. (Figure 12 shows a subject with arch wires ligated into place and elastics in position.)

Five subjects who did not require extraction of teeth were treated with the use of extra-oral forces from cervical headgear applied to the mandibular arch. The arch wires used were of the same dimension; however, no bends were incorporated into these arch wires other than the general configuration of the arch and a slight curve in the posterior segments to conform to the general arch form. There were two sections of .010 open coil spring placed on the wire to advance two sliding hooks (Figure 13). The distal end of the section of open coil spring was placed against the bracket of the mandibular first premolar and the hook was advanced by the coil to a position mesial to the mandibular canine. In these subjects, the bands on the mandibular canine teeth were removed in order to allow the hook to be advanced a greater distance without any interference from the bracket on the canine band. The hooks from the cervical headgear were attached bilaterally to the sliding hooks in the mouth. The cervical headgear hooks in turn were attached extraorally to the material from which the headgear was constructed by means of "X" type orthospec elastics. (Figure 14 shows an example of the cervical headgear, the manner in which it was worn, and the way in which the extra-

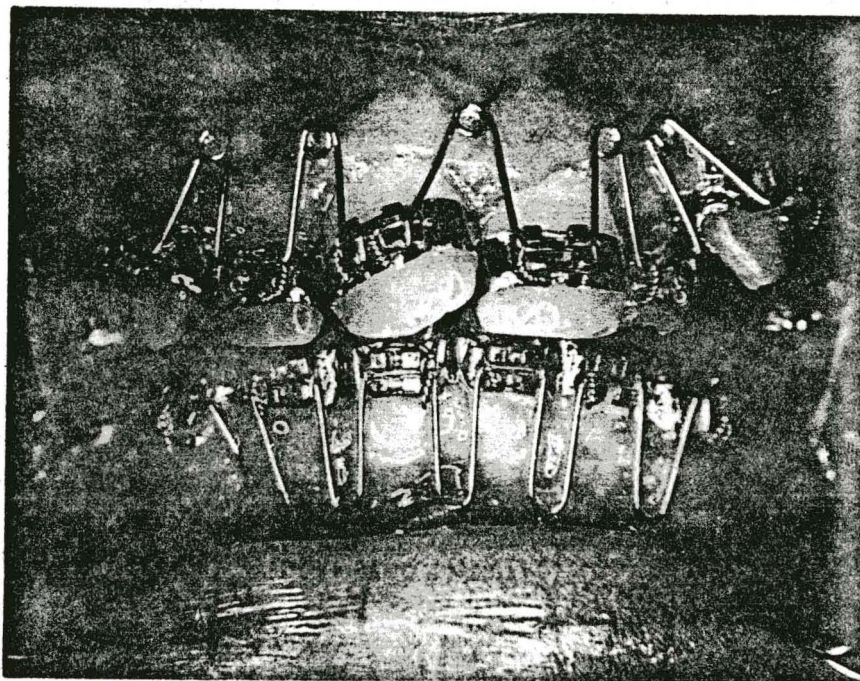


FIGURE 12

ARCH WIRES IN PLACE AND
ELASTICS IN POSITION

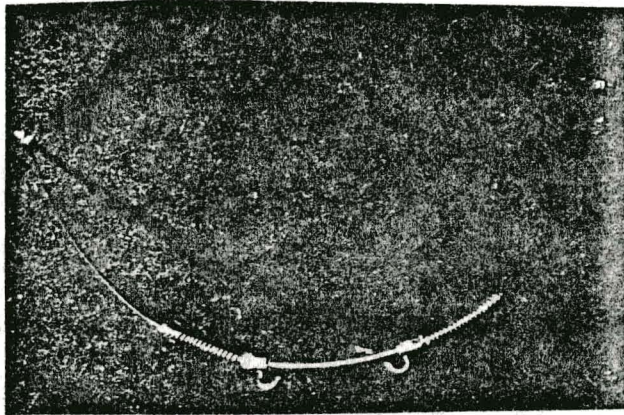


FIGURE 13

ARCH WIRE WITH ATTACHMENTS FOR USE WITH
EXTRA-ORAL FORCES FROM CERVICAL HEADGEAR

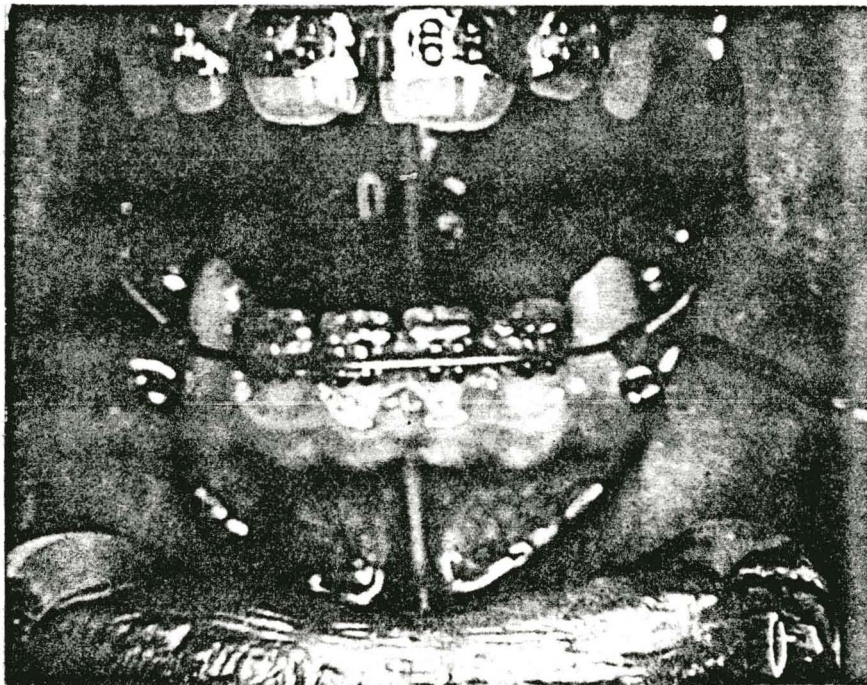


FIGURE 14

THE APPLICATION OF EXTRA-ORAL FORCES FROM
CERVICAL HEADGEAR TO THE MANDIBULAR ARCH

oral hooks were attached from it to the mouth.) In these subjects, heavy 1/4 inch elastics were also worn in the same triangular manner as previously described.

The same type of wire was used in all of the arch wires for the other subjects. These arch wires, however, were used primarily to level the mandibular plane of occlusion only. The arch wires were simply fashioned to the shape of an ideal arch, individualized for arch width and form for each subject, tempered, and inserted. They carried no attachments or bent-in vertical helical loops or hooks (see Figure 15). In these cases, 1/4 inch heavy elastics were applied in the previously described triangular fashion.

The arch wires used for consolidation (closure) of spaces were identical in both extraction and non-extraction subjects. (Figure 16.) These wires had hooks bent into the arch wires just distal to the lateral incisors in order that elastics spanning from the anchor units could be attached. First order bends were also employed in these ideal arches.

2. Edgewise technique

Each of the subjects was fully banded. The last bands in the arch, whether placed on the first or second molars, were provided with 0.022 x 0.028 inch edgewise buccal tubes, 1/4 inch in length. The tubes were angulated 5° from the horizontal in order to give the teeth a distal tip-back when a straight arch

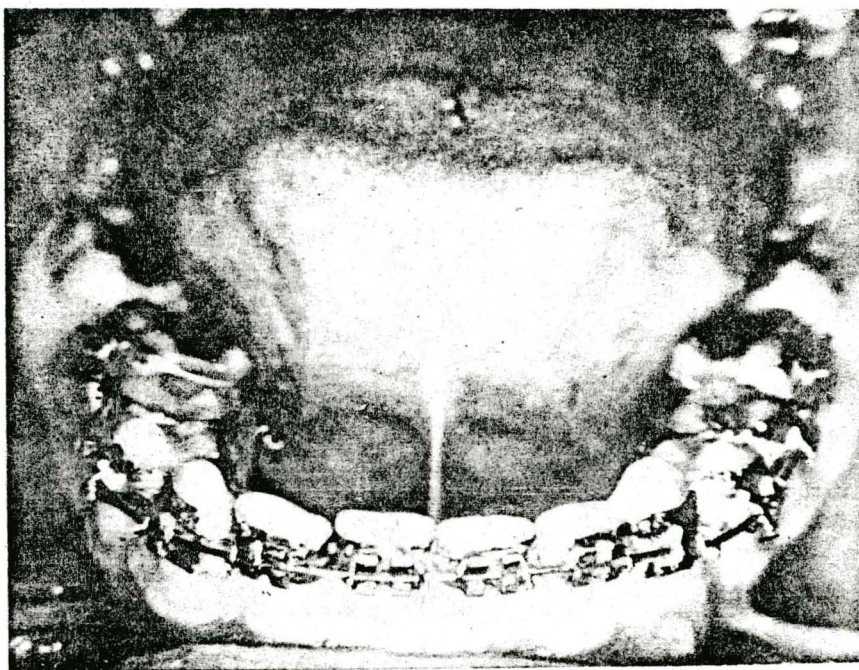


FIGURE 15

IDEAL ARCH WIRE WITH NO ATTACHMENTS FOR
LEVELLING MANDIBULAR OCCLUSAL PLANE

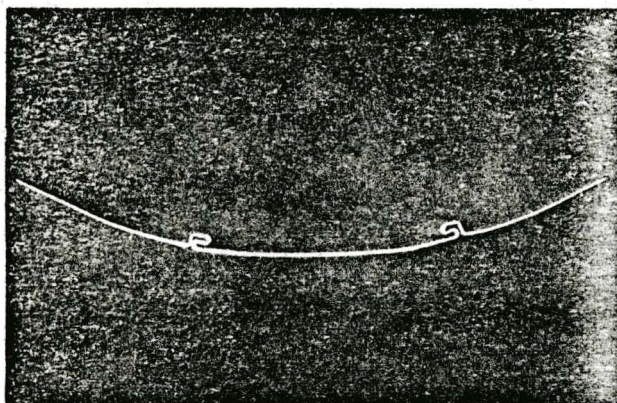


FIGURE 16

ARCH WIRE FOR CONSOLIDATION OF SPACES

wire was inserted into the tubes. In cases where second molars were banded, the first molar bands carried two single edgewise brackets. The premolar and canine bands were provided with one single edgewise bracket each, while those used for the maxillary central incisors were wide siamese, for the maxillary laterals medium siamese, and those for the mandibular incisors, junior siamese brackets. All of the brackets had zero degree torque slots, and none of them were angulated from the horizontal (Figure 17).

The initial levelling arch wires for the patients in this study were designed from 0.016 inch diameter semi-spring temper Elgiloy wire. Prior to their insertion, all arch wires were heat treated to spring hardness. In cases of severe crowding of the anterior teeth, lingually locked or rotated incisors, or partially erupted canines, the "Loyola-Jarabak Light Wire Technique" was employed during the stage of levelling (Figure 11).

In cases with normally aligned anterior teeth, "ideal" arch wires with bent-in tie-back loops and mild tip-back bends were formed of Number 1 temper, 0.016 inch diameter Tru-Chrome (18-8) wire (Figure 18). The tie-back loops were placed about one to two millimeters mesial to the buccal tubes and served to keep the arch wire taut by tying it back to the buccal hooks on the molar tubes.

The diameter of these levelling arch wires, and the

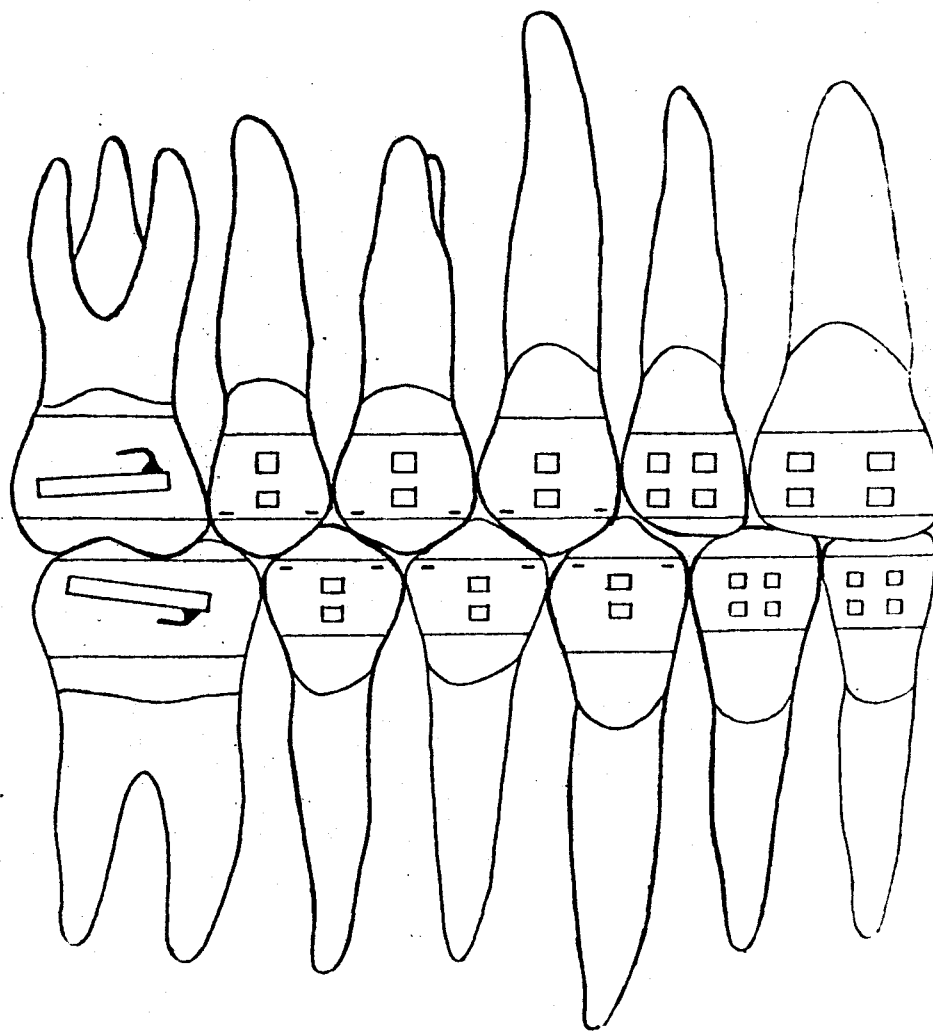


FIGURE 17

DIAGRAM OF EDGEWISE BRACKETS AND BUCCAL TUBES.
THE BUCCAL TUBES ARE ANGULATED FIVE DEGREES FOR
THE DISTAL TIPPING OF THE TERMINAL MOLARS. THE
BRACKETS ARE NOT ANGULATED AND HAVE ZERO DEGREE
TORQUE SLOTS.

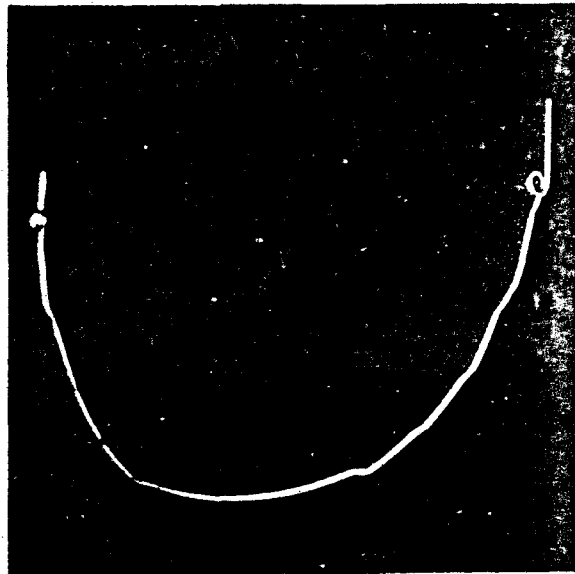


FIGURE 18

LEVELLING ARCH WIRE WITH MILD TIP-BACK
BENDS AND TIE-BACK LOOPS CONSTRUCTED
FROM 0.016 INCH DIAMETER WIRE

degree of their tip-back bends, were increased with each appointment until the brackets were aligned to allow the engagement of rectangular arch wires. The phase of levelling was then completed by placing an ideal 0.021 x 0.027 inch round edge rectangular arch wire with bent-in tie-back loops mesial to the buccal tubes. (Figure 19.)

After the levelling stage is completed, anchorage preparation is begun. According to Tweed, anchorage preparation is that phase of treatment when teeth selected for anchorage are uprighted and tipped distally to a position from which they are assumed to resist anterior displacement more effectively. This is accomplished by incorporating tip-back bends into the arch wire in conjunction with a distal force applied to the mandibular arch. Class III elastics supplied the distal force which is effected through intermaxillary elastics which are extended diagonally from soldered hooks on the anterior segment of the mandibular arch wire, interproximally between the mandibular lateral incisors and canine teeth, to similar hooks on the buccal tubes in the posterior segments of the maxillary arch. (Figure 20.) In order to counteract the reciprocal mesial force on the maxillary arch resulting from these class III elastics, resistance bends are placed in the maxillary arch wire and headgear is employed which exerts a distal force on the maxillary arch. The force incorporated into the headgear must be greater than the

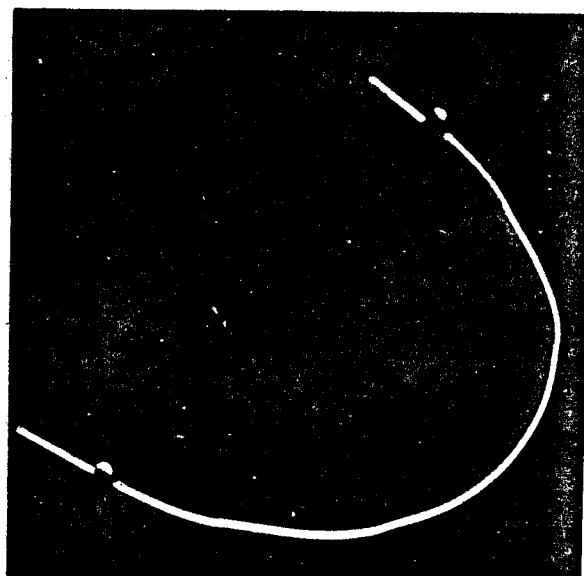


FIGURE 19

IDEAL RECTANGULAR LEVELLING ARCH WIRE WITH
TIE-BACK LOOPS, CONSTRUCTED OF 0.021 x 0.027
INCH NUMBER 1 TEMPER TRU-CHROME WIRE

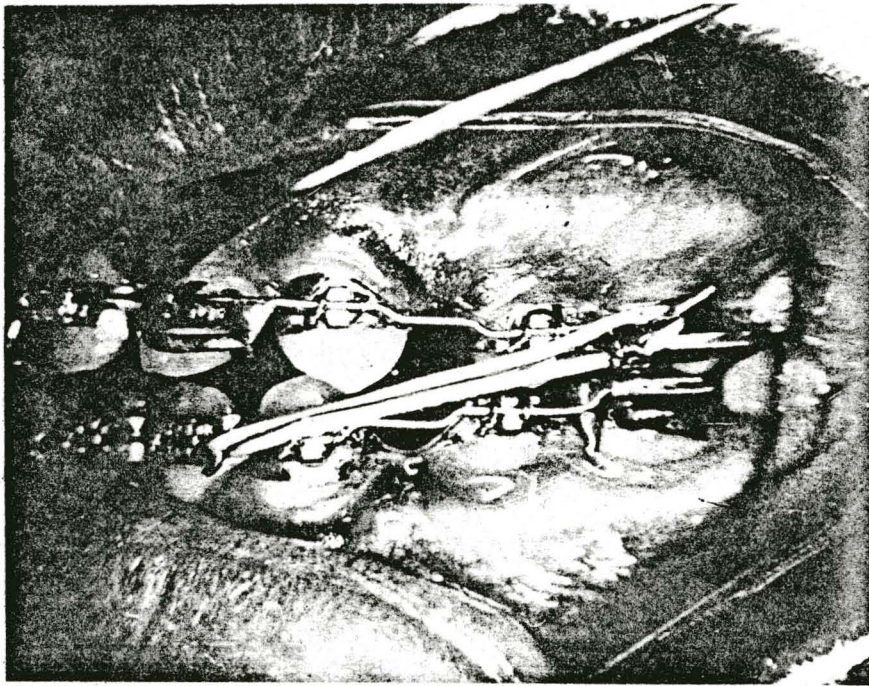


FIGURE 20

LATERAL INTRA-ORAL VIEW OF 0.021 x 0.027 INCH
RECTANGULAR ARCH WIRES WITH TIP-BACK BENDS IN
CONJUNCTION WITH CLASS III ELASTICS AND CERVICAL
HEADGEAR TO THE MAXILLARY ARCH AS UTILIZED IN THE
EDGEWISE TECHNIQUE DURING ANCHORAGE PREPARATION

force resulting from the class III elastics in order to assure effective anchorage in the maxillary arch.

In the mandibular arch when the incisor teeth are overlying the denture base and are in a lingual axial inclination with the crowns of the posterior teeth tipped distally, anchorage is then considered to be established. The arch wire is changed to 0.0215 x 0.028 inch stabilizing arch wire to permit the use of class II elastics. The maxillary arch wire is changed to a 0.021 x 0.025 inch resilient arch wire to effect distal mass movement under class II elastic force. Class II elastic hooks are soldered incisally on the maxillary arch wire mesial to the canine bracket area. Class II elastics extend from this hook on the maxillary arch wire to a hook placed gingivally on the buccal tube of the terminal mandibular anchor molar. (Figure 21.) Distal movement of the maxillary teeth is continued until these teeth have been carried half the width of a premolar farther distally than normal and until the incisor teeth are biting end-to-end. This allows for a certain amount of return movement that always occurs when the elastics are removed.

All subjects were instructed to change the intra-oral elastics three to four times daily. The appointments were at two week intervals for check-ups and necessary appliance changes.

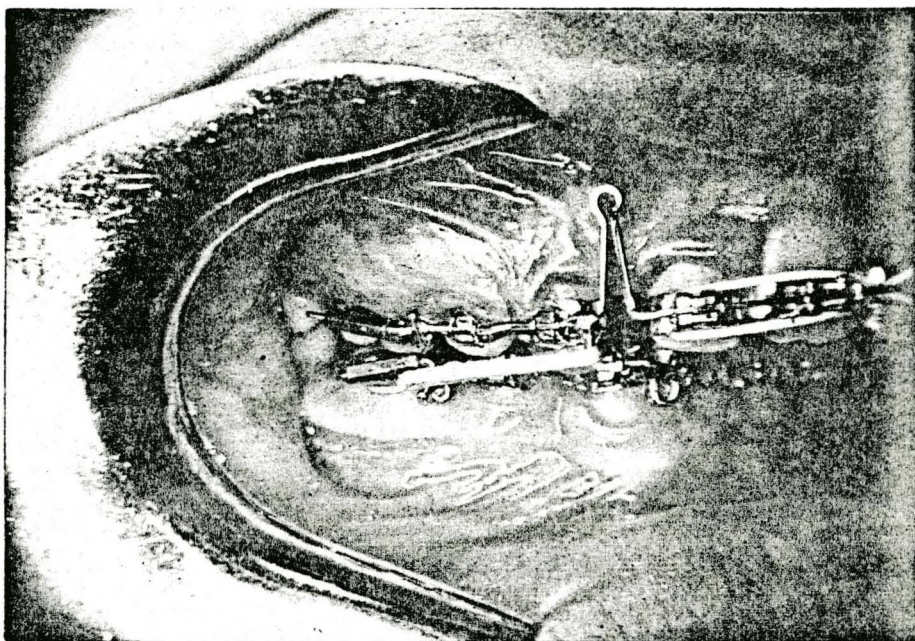


FIGURE 21

LATERAL INTRA-ORAL VIEW WITH CLASS II
ELASTICS AS UTILIZED IN EDGEWISE TECHNIQUE
TO EFFECT DISTAL MASS MOVEMENT IN MAXILLARY
ARCH

CHAPTER IV

EXPERIMENTAL RESULTS

The findings of this investigation will be reported in three parts corresponding to the three methods used for evaluation of the roentgenographic data. Part one is based on the interpretation of the markings on the reference strips described in Chapter III, part two deals with the findings from the visual appraisal of the serial slide projections, and the third part contains the findings derived from a cephalometric appraisal of the mandibular molar teeth. Parts one and two will disclose the types of tooth movements observed and part three will be concerned with the amounts of tooth movements.

The results from the two types of treatment will be reported separately.

1. Results from edgewise appliance therapy

A. Interpretation of the reference strips

Only one combination of changes in the periodontal width was observed during the twelve week period when various types of class II forces were in effect: an increase of the periodontal width at points C and D (distal marginal and distal apical areas) with a corresponding decrease at points B and A (mesial marginal and mesial apical areas). This was interpreted as a

result of a mesial translation.

In comparing the markings on the reference strips of the original roentgenograms with those recorded from the replicates, a very close correlation was found between the two. In 158 of the total 176 sections marked on the 22 reference strips, all of the original and replicate markings coincided at the various points (A, B, C, D) indicating agreement. In each of the 18 sections, one of the replicate recordings was not in alignment with its corresponding original recording; however, the positions indicated that the dimensional changes in the periodontal width occurred in the same direction as the original recording. Therefore, the interpretation of the type of movement was the same for each set of original and replicate records.

B. Visual appraisal

The prevalent type of tooth movement seen during the use of class II forces was a mesial bodily movement or translation. The points of rotation are estimated to be in the cervical one-third of the roots near the alveolar crest. By comparing this series of x-rays with the pre-treatment series and the series taken after anchorage preparation, an obvious mesial movement was noted in most cases with a distinct thickening of the cribriform plate along the distal root surface from the marginal area at the alveolar crest to the apex.

C. Findings from the cephalometric measurements

1. General analysis

The measurements from the lateral headplates taken after anchorage preparation and after twelve weeks of class II forces revealed that the gross movement of the mandibular first molars during this period of treatment was a mesial bodily movement with tipping. The measurements are tabulated on the data sheet in Figure 22.

Column A contains the values of the right and left sides after anchorage preparation; Column B shows the measurements taken after twelve weeks of class II forces. The differences between A and B are recorded in Column C, indicating the loss of anchorage. All the figures represent measurements taken in millimeters as described in the previous chapter. The figures in the data sheet are arranged in Table III to show the analysis between extraction and non-extraction cases. In every case there is a mesial movement of the mandibular first molar teeth due to the class II forces. It will be noticed that the average movement of both crowns and roots is considerably more in the extraction cases as compared with the non-extraction cases.

Table IV analyses the three types of mesial movements taking place. There was a mesial translation of anchor teeth where crown and root moved forward but the roots moved forward more than the crowns.

2. Statistical analysis

The data shown in Figure 22 were graphed in a histogram (Figure 23) and analyzed statistically by Fisher's Analysis of Variance without transformation. The computations of this analysis are shown in Figure 24 and will be discussed in detail to show their importance in interpreting the results of this investigation.

It is interesting to note the magnitude of experimental error, or experimental uncertainty, from all sources which have been encountered. This work has displayed a reasonable error amounting to about 6 per cent of the mean measurement (coefficient of variation equals 0.059) which means that any given measurement would be expected to have an accuracy of plus or minus about 2 mm. (The 99 per cent Confidence Limits are ± 2.42 mm.)

Referring to the ANOV table (Figure 24) the several interactions which have taken place are shown in the lower part of the table. There were no significant interactions between "Sides x Treatments," "Sides x Position," "Treatments x Positions," nor were there any significant third order interactions.

The interaction taking place between "Patients x Sides" is shown graphically in Figure 25. In this graph, the right side measurements for patients #1, 2, 7, 8, 9, and 10 are shown on the top line and the left side measurements are on the bottom line. The measurements equal the combined total of the

DATA SHEET

PATIENT	A (BEFORE)		B (AFTER)		C (DISPLACEMENT)	
	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
1 CROWN	16.5	21.0	12	15.0	-4.5	-6.0
1 APEX	10.0	15.0	8	15.0	-2.0	0
2 CROWN	18.5	18.5	14.5	14.5	-4.0	-4.0
2 APEX	13.5	13.5	9	9	-4.5	-4.5
3 CROWN	19.0	19.0	17.5	18	-1.5	-1.0
3 APEX	17.0	17.0	15	15	-2.0	-2.0
4 CROWN	20.0	20.0	18	18	-2.0	-2.0
4 APEX	15.0	15.0	11	12	-4.0	-4.0
6 CROWN	14.5	21.0	13	19	-1.5	-2.0
6 APEX	11.0	17.5	9	14	-2.0	-3.5
7 CROWN	14.5	14.5	13	13	-1.5	-1.5
7 APEX	13.0	13.0	11	11	-2.0	-2.0
9 CROWN	17.0	21.5	17.0	20.5	0	-1.5
9 APEX	12.5	20.0	11	16	-1.5	-4.0
10 CROWN	13.0	17.0	12	15	-1.0	-2.0
10 APEX	12.0	15.5	11	14	-1.0	-1.5
11 CROWN	18.5	18.5	16.5	16.5	-2.0	-2.0
11 APEX	16.0	16.0	15	15	-1.0	-1.0
13 CROWN	10.0	11.5	9	11	-1.0	-0.5
13 APEX	10.0	14.0	5	7.5	-5.0	-6.5
14 CROWN	15.5	15.5	13.5	13.5	-2.0	-2.0
14 APEX	10.0	10.0	8	8	-2.0	-2.0

FIGURE 22

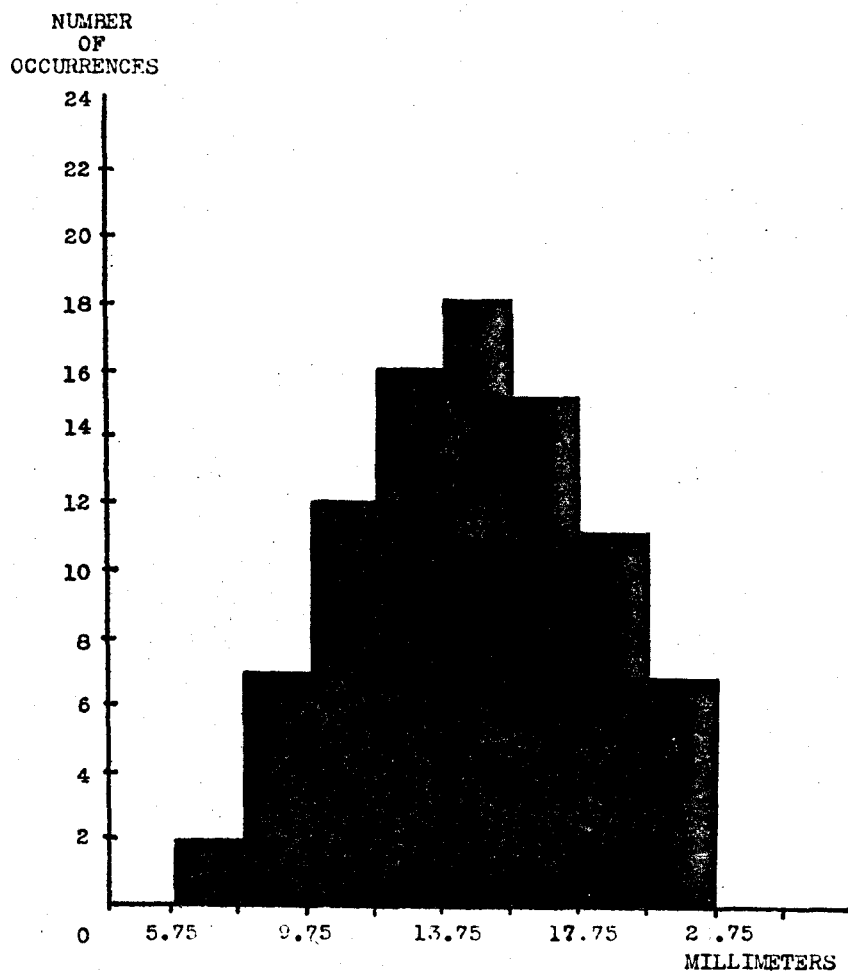
THE VALUES IN THE BODY OF THIS TABLE REPRESENT
 CEPHALOMETRIC MEASUREMENTS TAKEN IN MILLIMETERS.
 COLUMN C INDICATES LOSS OF ANCHORAGE DUE TO
 CLASS II FORCES

TABLE III
 MESIAL MOVEMENT OF CROWNS AND ROOTS IN
 PATIENTS DURING CLASS II FORCES
 WITH EDGEWISE APPLIANCES

Patient	Crowns (Total R & L Sides)	Roots (Total R & L Sides)
<u>Extraction Cases</u>		
1	10.5	2.0
2	8.0	9.0
3	2.5	4.0
4	4.0	8.0
6	3.5	5.5
7	3.0	4.0
13	1.5	11.5
14	4.0	4.0
Total	37.0 mm	48.0 mm
Mean	4.62 mm	6.0 mm
<u>Non-Extraction Cases</u>		
9	1.5	5.5
10	3.0	2.5
11	4.0	2.0
Total	8.5 mm	10.0 mm
Mean	2.83 mm	3.33 mm

TABLE IV
DISTRIBUTION OF TOOTH MOVEMENTS IN
PATIENTS WEARING EDGEWISE
APPLIANCES DURING
CLASS II FORCES

Type of Movement	Transla- tion by Tipping	Mesial Tipping	Mesial Transla- tion
<u>Extraction Cases</u>			
Number of Sides	12	2	2
Total Movement (mm)			
Crowns	20.0	10.5	4.0
Roots	30.5	2.0	4.0
Mean			
Crowns	1.66	5.25	2.0
Roots	2.54	1.0	2.0
<u>Non-Extraction Cases</u>			
Number of Sides	2	3	1
Total Movement (mm)			
Crowns	1.5	4.0	1.0
Roots	5.5	2.0	1.0
Mean			
Crowns	.75	2.0	1.0
Roots	2.75	1.0	1.0



HISTOGRAM OF THE CEPHALOMETRIC MEASUREMENTS
EDGEWISE PATIENTS

FIGURE 23

HISTOGRAM OF PATIENTS WEARING
EDGEWISE APPLIANCES SHOWING
NUMBER OF TIMES EACH MEASUREMENT
OCCURS

ANOV TABLE
(ALL COMPLETE POPULATIONS)

SOURCES	D.F.	S.S.	M.S.	F	SIGNIFICANCE
PATIENTS	10	432.77	43.277	54.01	5% 1% xxx 2.07 2.79
SIDES	1	92.04	92.04	7.87	5% 1% xxx 4.96 10.04
TREATMENTS	1	129.56	120.56	120.47	5% 1% xxx 4.96 10.04
POSITIONS	1	248.90	248.90	42.65	5% 1% xxx 4.96 10.04
P X S	10	118.33	11.833	14.76	5% 1% xxx 2.07 2.79
P X T	10	17.32	1.732	2.16	5% 1% x 2.07 2.79
P X POS	10	58.36	5.836	7.28	5% 1% xxx 2.07 2.79
S X T	1	.56	.56	<.1	N.S.
S X POS	1	1.65	1.65	2.05	N.S.
T X POS	1	1.93	1.93	2.48	N.S.
RESIDUAL	41	32.85	.8012		
TOTAL	87	1,125.27			

Standard Deviation of Error = 0.895 mm.

and the 99% CONFIDENCE LIMITS ARE $\pm (2.704 \times 0.895) = \pm 2.42$ mm.

S.S. - Sums of Squares

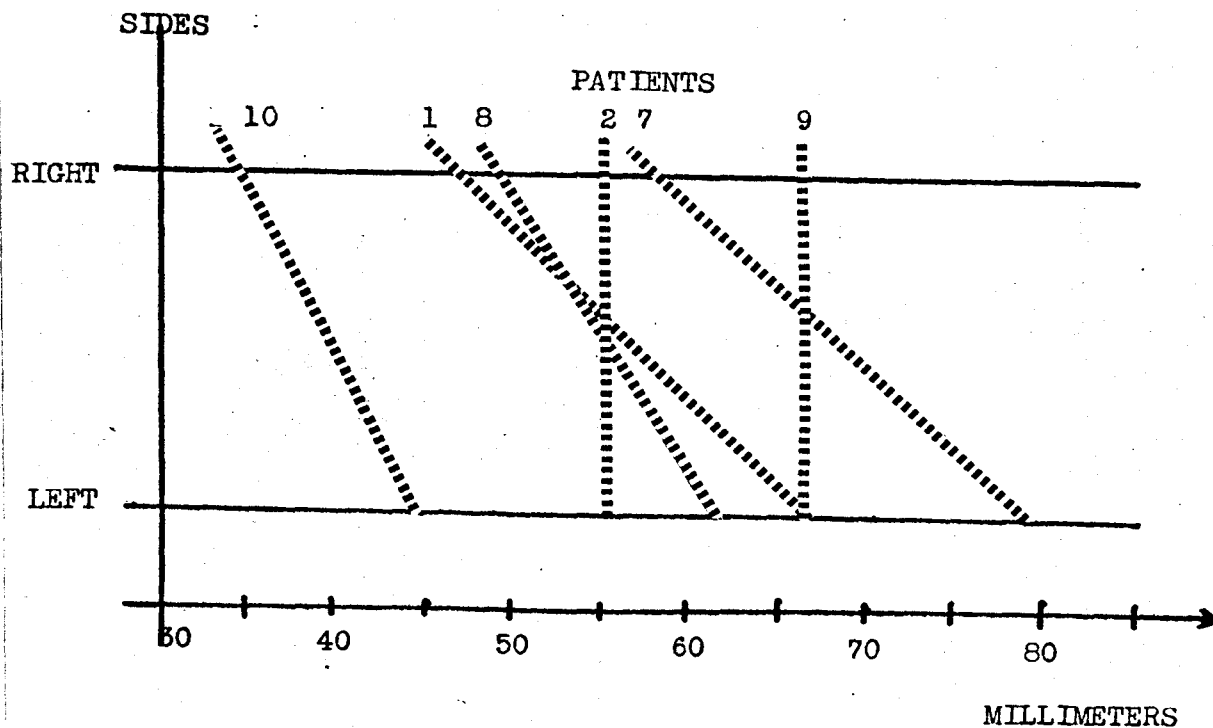
M.S. - Means of Squares

D.F. - Degrees of Freedom

FIGURE 24

XXX = HIGHLY SIGNIFICANT VARIANCE RATIO

N.S. = NON-SIGNIFICANT VARIANCE RATIO



GRAPH OF PATIENTS X SIDES INTERACTION

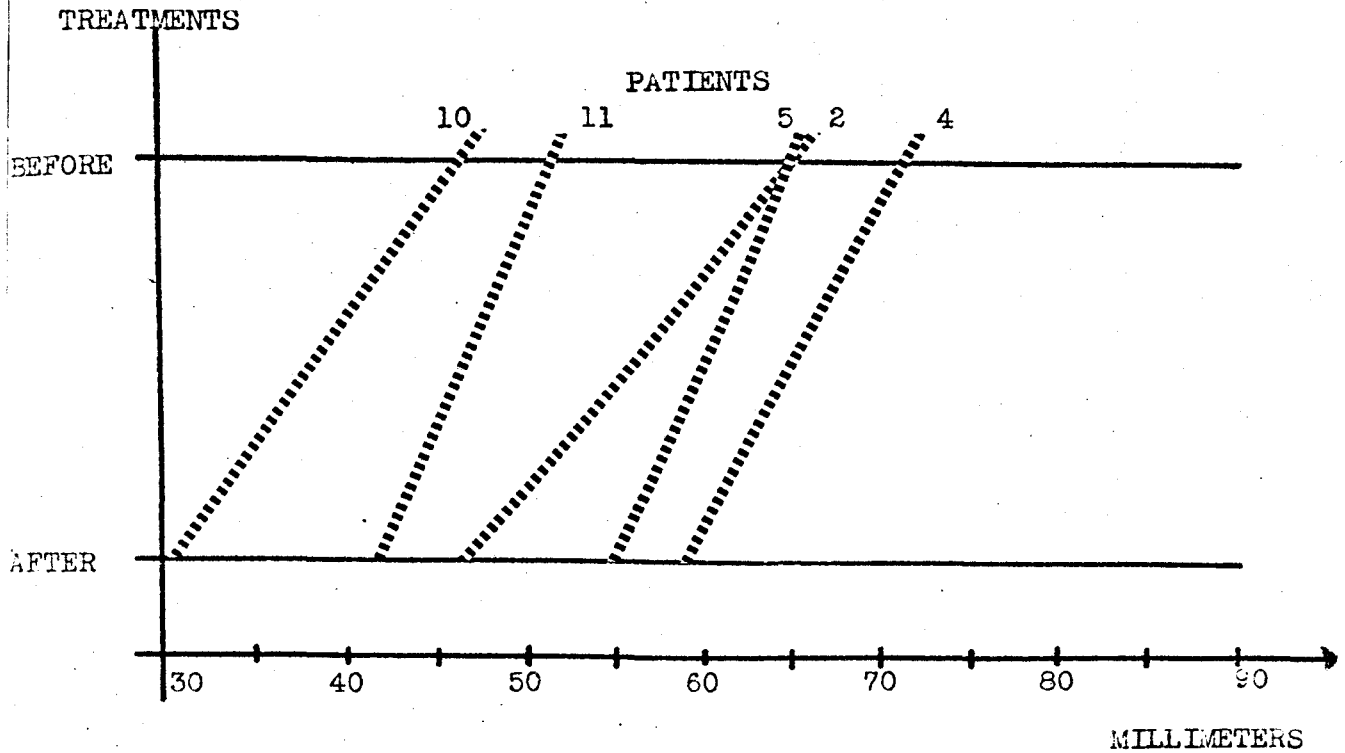
FIGURE 25

THE LACK OF PARALLELISM OF SOME DOTTED
CONNECTING LINES INDICATES AN APPARENT
DIFFERENCE BETWEEN THE DISTANCE OF RIGHT
AND LEFT MANDIBULAR MOLAR TEETH FROM THE
MIDLINE IN PATIENTS WEARING EDGEWISE
APPLIANCES

crown and apex of each side before and after treatment and have been computed for all eleven patients in a separate "Patients x Sides" table which is part of the Analysis of Variance computations. The corresponding measurement points for each patient are connected by dotted lines for ease of comparison. If all these dotted connecting lines were parallel, or nearly so, they would suggest no interaction; but some of them are vertical while others are diagonal that there is a difference in the teeth measured from the midline in these patients is significantly illustrated in this graph.. This is to be expected from the fact that there are various types of arch forms and growth patterns in different individuals.

The graph in Figure 26 illustrates the "Patient x Treatment" action. The dotted connecting lines in this graph point out a close similarity in effect of treatment in many of the patients. There would be in fact the same similarity shown in all the patients if they were all plotted because in each instance the crowns and roots showed a decrease in distance in relation to the reference line at the symphysis indicating a movement in a forward, or mesial direction.

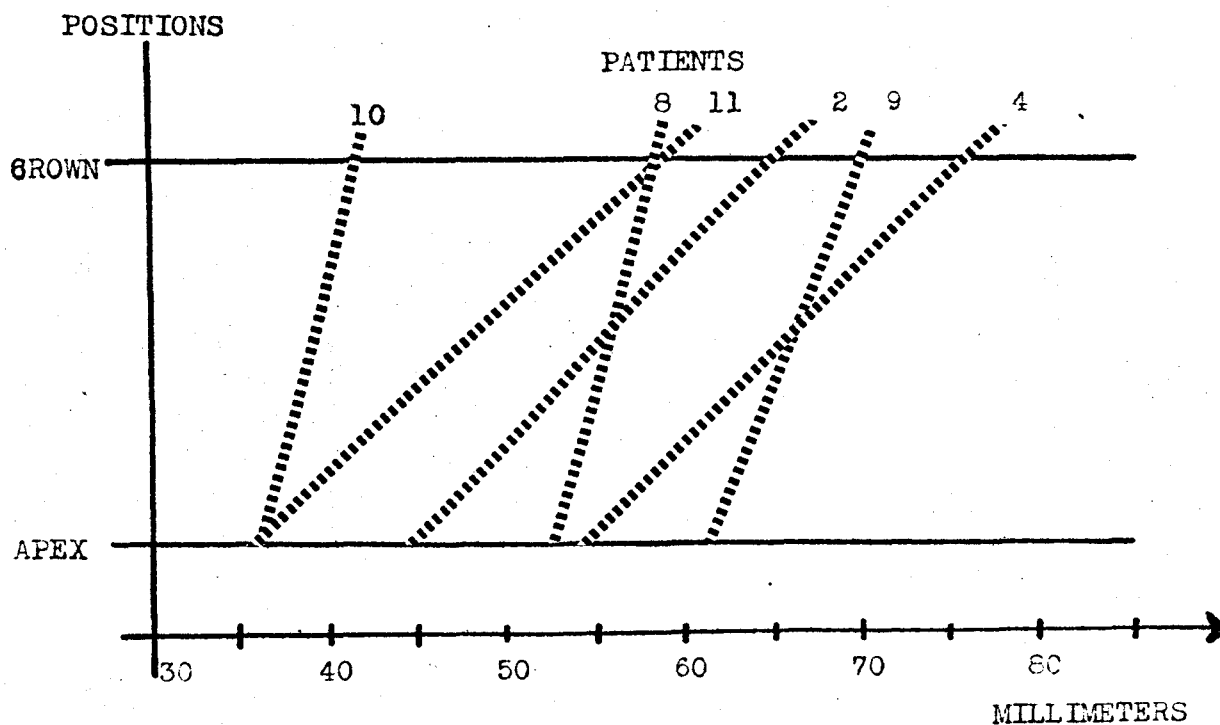
The interaction between "Patients x Positions" is demonstrated graphically in Figure 27. The dotted connecting lines show similarities in patients in the relative distance of crown and root from the reference line and that the apex was always



GRAPH OF PATIENTS X TREATMENTS INTERACTION

FIGURE 26

THE PARALLELISM OF DOTTED CONNECTING LINES
INDICATES THE SIMILARITY IN EFFECTS OF TREAT-
MENT IN PATIENTS WEARING EDGEWISE APPLIANCES



GRAPH OF PATIENTS X POSITIONS INTERACTION

FIGURE 27

THE DOTTED CONNECTING LINES SHOW SIMILARITY
IN PATIENTS RELATIVE DISTANCE OF POSITIONS OF
CROWNS AND ROOTS FROM SYMPHYSIS, IN PATIENTS
TREATED WITH EDGEWISE MECHANICS

closer. It must be remembered, however, that the measurements compiled to effect this chart consist of the "before" and "after" treatment distances to the inner border of the symphysis. The "before" treatment measurements are actually the result of anchorage preparation mechanics where it has been shown (Stier 1962) that the crowns were tipped distally an average distance of 2 mm, while the roots moved in a mesial direction on the average of 2.5 mm. The "after" treatment measurements, after twelve weeks of class II forces, indicated a mesial movement of the crown of an average 3.06 mm, and a mesial movement of the root of 3.36 mm, a translation by tipping. This explains why the line is so diagonal in some cases with the crown being so much further back from the reference line than the roots.

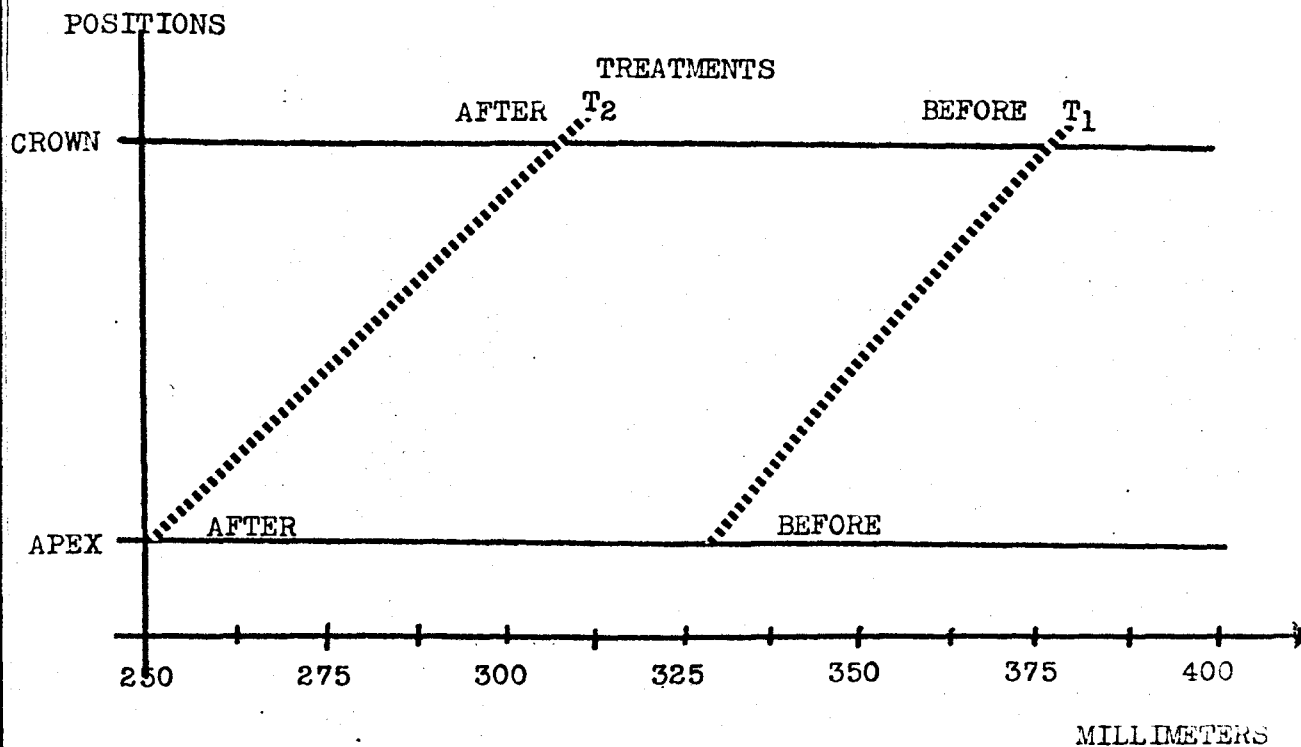
While there was no significant interaction between "Treatments x Positions," (Figure 28) this graph serves to point out the one type of movement which took place in all patients requiring class II forces.

The parallelism in the dotted connecting lines shows a forward movement of approximately the same magnitude in both crowns and roots. The distance involved represents the total distance for all crowns and roots of all patients.

2. Results from light wire therapy

A. Interpretation of the reference strips

A predominant change taking place in the periodon-



GRAPH OF POSITIONS X TREATMENTS INTERACTION

T₁ = Before Treatment

T₂ = After Treatment

FIGURE 28

PARALLELISM IN THE DOTTED CONNECTING
LINES SHOWS GENERAL MESIAL MOVEMENT
OF BOTH CROWNS AND ROOTS AFTER TREAT-
MENT

tal width during this period of consolidation of spaces and class II mechanics to completion of treatment was a decrease at points A and B (mesial marginal and mesial apical areas) and a corresponding increase at points C and D (distal marginal and distal apical areas). This is indicative of a mesial tipping movement. The axis of rotation in general was in the apical one-third of the roots. In comparing the markings on the reference strips of the original roentgenograms with those recorded from the replicates on duplicate reference strips, a very close correlation was found between the two. In 196 of the total 224 sections marked on the 28 reference strips, all the original and replicate recordings were in complete agreement at the various points (A, B, C, D). In each of the 28 sections, one of the replicate recordings was not in alignment with its corresponding original recording; however, the positions indicated that the dimensional changes in the periodontal width occurred in the same direction. Therefore, the interpretation of the type of movement was the same for each set of the original and replicate records.

B. Visual appraisal

The most common observation noted in over 75 per cent of the areas involved was a return to normal of the periodontal width and of the cribriform plate. In some cases where there had been excessive mesial movement of the mandibular first molars to deliberately close spaces, there was still evidence of a thick-

ening of the cribriform plate along the distal surface of the tooth from the cervical margin at the alveolar crest to the tip of the apex. The periodontal space was wider on the distal root surface and thinner on the mesial root surface.

C. Cephalometric measurements

1. General analysis

The measurements shown in Figure 29 represent the results of the three phases of treatment under study. Column A is the position of the crown and apex before treatment and is measured from a line drawn perpendicular to the mandibular plane at the border of the inner symphysis as explained in Chapter III. Column B represents the position of crown and apex after anchorage preparation. Column C represents a period during the consolidation stage and Column D are measurements taken at the completion of treatment.

The measurements made upon the lateral headplates taken during the consolidation stage and at the completion of treatment showed that there were several types of movement during this period. An analysis of the movements of the crowns and roots during this period of extraction and non-extraction cases is listed in Table V. Gross movements of crowns and roots for both sides of each patient are listed and the mean is given for movements of crowns and roots.

For a more detailed analysis, Table VI lists the

PATIENT	A		B		C		D	
	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
1	CROWN	16.5	16.5	16.0	16.0	16.5	16.0	16.0
	APEX	20.0	20.0	19.0	19.0	19.0	19.0	19.0
2	CROWN	18.0	20.0	21.0	24.5	16.0	23.0	18.0
	APEX	18.0	21.0	18.0	21.0	16.0	19.0	16.0
3	CROWN	16.0	18.0	19.0	20.0	17.0	18.0	17.0
	APEX	17.0	20.0	16.0	18.0	14.0	16.0	15.0
4	CROWN	10.0	15.0	15.5	19.5	15.0	19.0	14.0
	APEX	10.0	15.0	15.5	20.5	14.0	18.0	14.0
5	CROWN	17.0	17.0	17.0	17.0	15.0	17.0	12.0
	APEX	16.0	16.0	16.0	16.0	12.0	16.0	12.0
6	CROWN	14.0	14.0	13.5	13.5	13.5	13.5	13.0
	APEX	17.0	17.0	17.0	17.0	15.0	15.0	14.0
7	CROWN	17.0	17.0	18.0	18.0	19.5	19.5	20.0
	APEX	19.0	19.0	19.0	19.0	18.5	18.5	19.0
8	CROWN	17.0	19.0	20.0	23.5	15.5	19.0	20.0
	APEX	16.5	18.5	16.0	20.0	14.0	17.0	15.0
9	CROWN	16.0	16.0	15.0	15.0	16.0	16.0	15.0
	APEX	15.5	15.5	14.5	14.5	15.0	16.0	15.0
10	CROWN	15.0	15.0	15.0	15.0	14.0	14.0	13.0
	APEX	14.0	14.0	14.0	14.0	12.0	12.0	12.0
11	CROWN	18.0	21.0	22.0	25.0	21.5	25.0	21.0
	APEX	14.5	20.0	16.5	22.0	16.5	19.0	16.0
12	CROWN	11.0	14.0	14.0	17.0	13.0	18.0	11.0
	APEX	11.0	15.0	9.5	16.0	7.5	13.5	7.5
13	CROWN	16.0	21.0	23.0	23.0	21.5	24.0	20.0
	APEX	16.0	21.0	18.0	19.0	16.0	20.0	15.0
14	CROWN	18.0	22.0	19.0	24.0	18.0	18.0	18.0
	APEX	22.0	23.0	21.0	23.0	20.0	21.0	19.0

FIGURE 29

THE VALUES IN THE BODY OF THIS
TABLE REPRESENT CEPHALOMETRIC
MEASUREMENTS TAKEN IN MILLIMETERS
FOR PATIENTS TREATED WITH LIGHT
FORCES

TABLE V
CHANGES IN CROWNS AND ROOTS IN PATIENTS
TREATED WITH LIGHT FORCES
CONSOLIDATION TO COMPLETION OF TREATMENT

Patient	Crowns (Total R & L Sides)	Roots (Total R & L Sides)
<u>Extraction Cases</u>		
4	-1.5 ^a	0
5	-5.0	-1.0
6	-1.0	-2.0
8	+7.5 ^b	+1.0
10	-2.0	0
12	-4.5	-1.0
14	<u>+1.0</u>	<u>-3.0</u>
Total	-5.5 mm	-6.0 mm
Mean	- .78 mm	- .85 mm
<u>Non-Extraction Cases</u>		
1	0	0
2	0	-1.0
3	0	+2.0
7	+1.0	-1.0
9	-2.0	-2.0
11	-1.5	-0.5
13	<u>-1.5</u>	<u>-1.5</u>
Total	-4.0 mm	-4.0 mm
Mean	- .59 mm	- .59 mm

^a - = Mesial Movement

^b + = Distal Movement

different types of movements occurring in extraction and non-extraction cases during this stage of treatment. Distal tip-back, mesial tipping, and mesial bodily movement represent the three kinds of movements which occurred.

For analysis of the changes taking place during the whole phase of treatment from pre-treatment records to completion of treatment (Columns A, D, Figure 29), Table VII was prepared. Extraction and non-extraction cases are analyzed for crowns and root movement, and the averages are listed. Table VIII gives a distribution of the specific types of movements occurring.

2. Statistical analysis

The data shown in Figure 29 were grouped in a histogram (Figure 30) and analyzed statistically by Fisher's Analysis of Variance without transformations. The computations of this analysis are shown in Figure 27 and will be discussed in detail to show their importance in interpreting the results of this investigation.

Referring to the ANOV table (Figure 31), the several interactions which have taken place are shown in the lower part of the table. There were no significant interactions between "Sides x Treatments," "Sides x Positions," and a three factor interaction of "Patients x Sides x Positions." Because the mean square of each interaction was less than one and not significant, they were all aggregated into the residual or error mean square.

TABLE VI
DISTRIBUTION OF TOOTH MOVEMENTS IN PATIENTS
TREATED WITH LIGHT FORCES
CONSOLIDATION TO COMPLETION OF TREATMENT

Type of Movement	Distal Tip- Back	Mesial Tipping	Mesial Trans- lation	No Movement
<u>Extraction Cases</u>				
Number of Sides	4	7	3	0
Total Movement (mm)				
Crowns	+8.5 ^a	-11.0	-3	0
Roots	-2.0 ^b	-1.0	-3	0
Mean				
Crowns	+2.12	-1.59	-1.0	0
Roots	-0.5	-.14	-1.0	0
<u>Non-Extraction Cases</u>				
Number of Sides	2	2	3	7
Total Movement (mm)				
Crowns	+1.0	-2.5	-2.5	0
Roots	-1.0	-1.0	-2.5	0
Mean				
Crowns	+0.5	-1.25	-.83	0
Roots	-0.5	-0.5	-.83	0

^a + = Distal Movement

^b - = Mesial Movement

TABLE VII
CHANGE IN CROWNS AND ROOTS IN PATIENTS
TREATED WITH LIGHT FORCES
PRE-TREATMENT AND POST-TREATMENT

Patient	Crowns (Total R & L Sides)	Roots (Total R & L Sides)
<u>Extraction Cases</u>		
4	+7.5 ^a	+7.0
5	-7.0 ^b	-7.0
6	-2.0	-6.0
8	+6.0	-3.0
10	-4.0	-4.0
12	+1.5	-6.0
14	+6.0	-8.0
Total	+8.0 mm	-27.0 mm
Mean	+1.14 mm	- 3.85 mm
<u>Non-Extraction Cases</u>		
1	-1	-2
2	+5	-5
3	+1	-5
7	+6	0
9	-2	-1
11	+6	+0.5
13	+7	-2.5
Total	+22 mm	-15 mm
Mean	+ 3.14 mm	- 2.14 mm

a + = Distal Movement

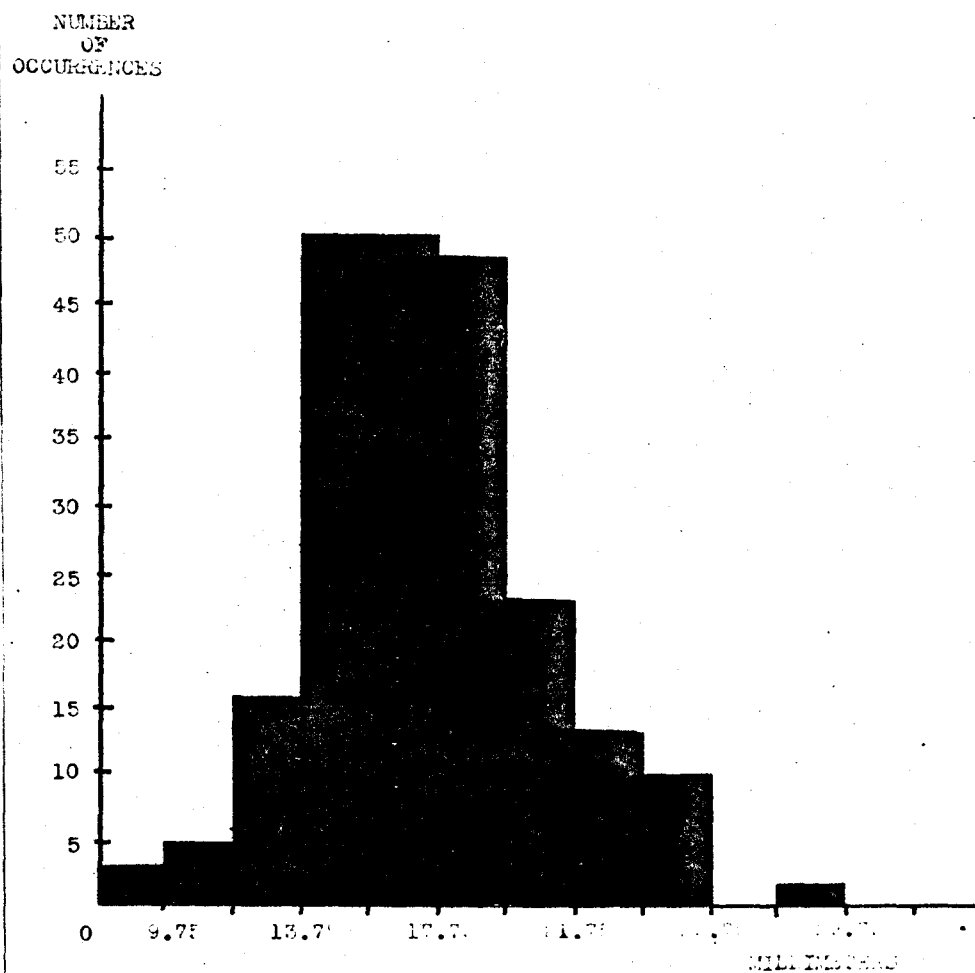
b - = Mesial Movement

TABLE VIII
DISTRIBUTION OF TOOTH MOVEMENTS IN PATIENTS
TREATED WITH LIGHT FORCES
PRE-TREATMENT AND POST-TREATMENT

Type of Movement	Distal Tip- Back	Mesial Trans- lation	Jiggling
<u>Extraction Cases</u>			
Number of Sides	6	6	2
Total Movement (mm)			
Crowns	+19.0 ^a	-13.0	+7.5
Roots	- 5.0 ^b	-17.0	+7.0
Mean			
Crowns	+ 3.16	- 2.16	+3.75
Roots	- .83	- 2.83	+3.50
<u>Non-Extraction Cases</u>			
Number of Sides	10	4	
Total Movement (mm)			
Crowns	+25.0	- 3.0	
Roots	-13.0	- 3.0	
Mean			
Crowns	+ 2.50	- .75	
Roots	- 1.30	- .75	

^a + = Distal Movement

^b - = Mesial Movement



HISTOGRAM OF THE CEPHALOMETRIC MEASUREMENTS

... LIGHT WIRE PATIENTS

FIGURE 30

HISTOGRAM OF PATIENTS TREATED WITH
LIGHT FORCES SHOWING NUMBER OF TIMES
EACH MEASUREMENT OCCURRED

ANOVA TABLE
(ALL COMPARISON POPULATIONS)

SOURCES	D.F.	S.S.	M.S.	F.	SIGNIFICANCE
PATIENTS	13	1,484.78	114.20	330.41	5% 1.35 1% 2.36 XXX
SIDES	1	281.26	281.26	813.83	5% 3.94 1% 6.19 XXX
TREATMENTS	3	63.47	21.16	7.08	5% 2.85 1% 4.33 XXX
POSITIONS	1	32.26	32.26	1.53	N.S.
P x S	13	218.21	16.79	48.58	5% 1.65 1% 2.36 XXX
P x T	39	116.75	2.99	8.65	5% 1.51 1% 1.79 XXX
P x POS	13	273.34	21.02	60.82	5% 1.85 1% 2.36 XXX
T x POS	3	59.68	19.89	7.74	5% 2.85 1% 4.33 XXX
P x T x POS	39	100.35	2.57	7.46	5% 1.51 1% 1.79 XXX
RESIDUAL	99	34.22	346		
TOTAL	224	2,664.32			

Standard Deviation of Error = 0.5878

and the 99% CONFIDENCE LIMITS are $\pm (2.617 \times 0.5878) \pm 1.53$ mm.

S.S. - Sums of Squares
M.S. - Means of Squares
D.F. - Degrees of Freedom

FIGURE 31

XXX = HIGHLY SIGNIFICANT VARIANCE RATIO

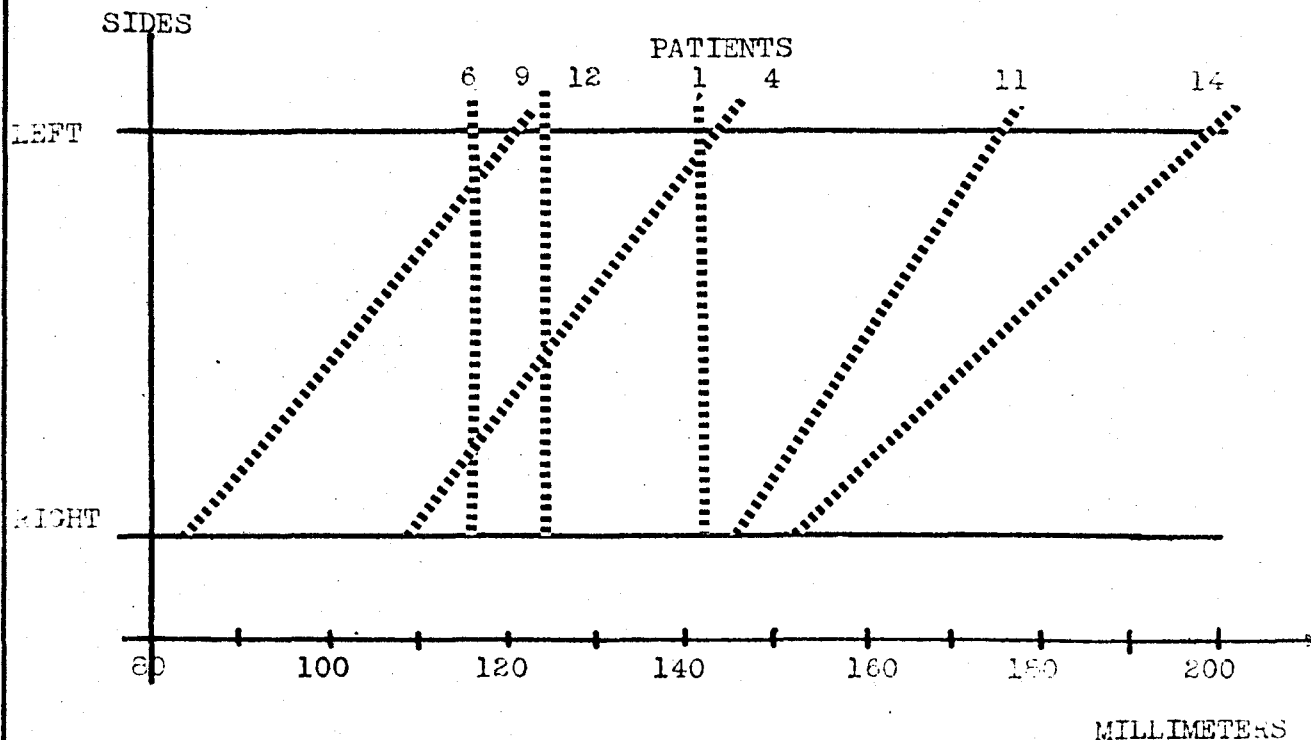
N.S. = NON-SIGNIFICANT VARIANCE RATIO

The graph shown in Figure 32, "Patients x Sides," is a compilation of all the measurements of both sides of all patients during the several stages of treatment. It is again pointed out that there is a lack of parallelism in many of the patients indicating the difference between the right and left sides. It must be noted, however, that in some patients the right and left sides are equidistant from the symphysis indicating symmetry.

The crowns and the roots of most of the patients in this study show a definite measurable difference as evidenced by the lack of parallelism of the dotted connecting lines in the "Patients x Positions" graph in Figure 33. It is obvious here that some of the teeth are going distally, some are moving mesially, and in a few instances, there is no apparent movement. These several types of movements are due to different mechanics. It will be explained later why it was necessary to use certain mechanics depending on treatment objectives.

Another aspect of the changes which had taken place in certain patients during treatment is illustrated in the "Patients x Treatment" interaction graph (Figure 34). Here again will be noticed the several types of changes taking place during treatment.

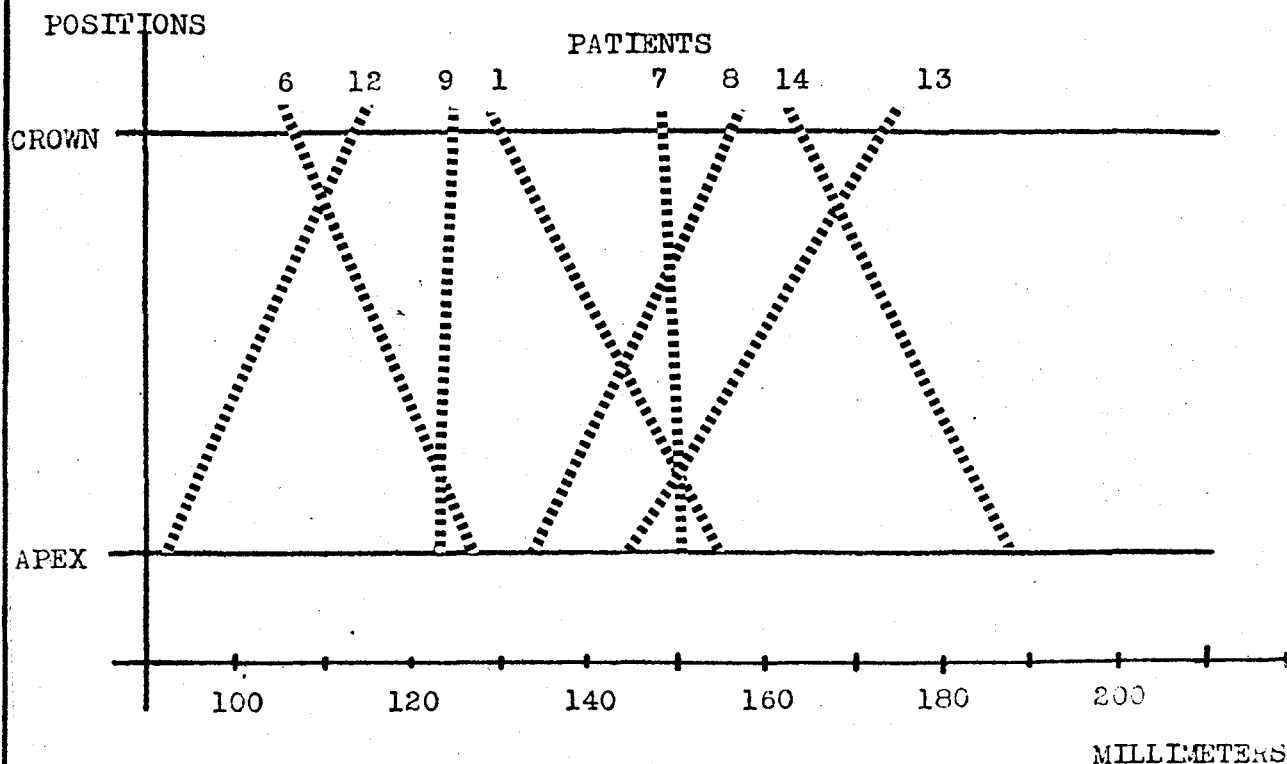
The overall picture of the results of light wire treatment is charted in Figure 35, the "Treatment x Positions"



GRAPH OF PATIENTS X SIDES INTERACTION

FIGURE 32

THE LACK OF PARALLELISM OF SOME DOTTED CONNECTING LINES INDICATES AN APPARENT DIFFERENCE BETWEEN THE DISTANCE OF RIGHT AND LEFT MANDIBULAR FROM THE MIDLINE IN PATIENTS TREATED WITH LIGHT FORCES

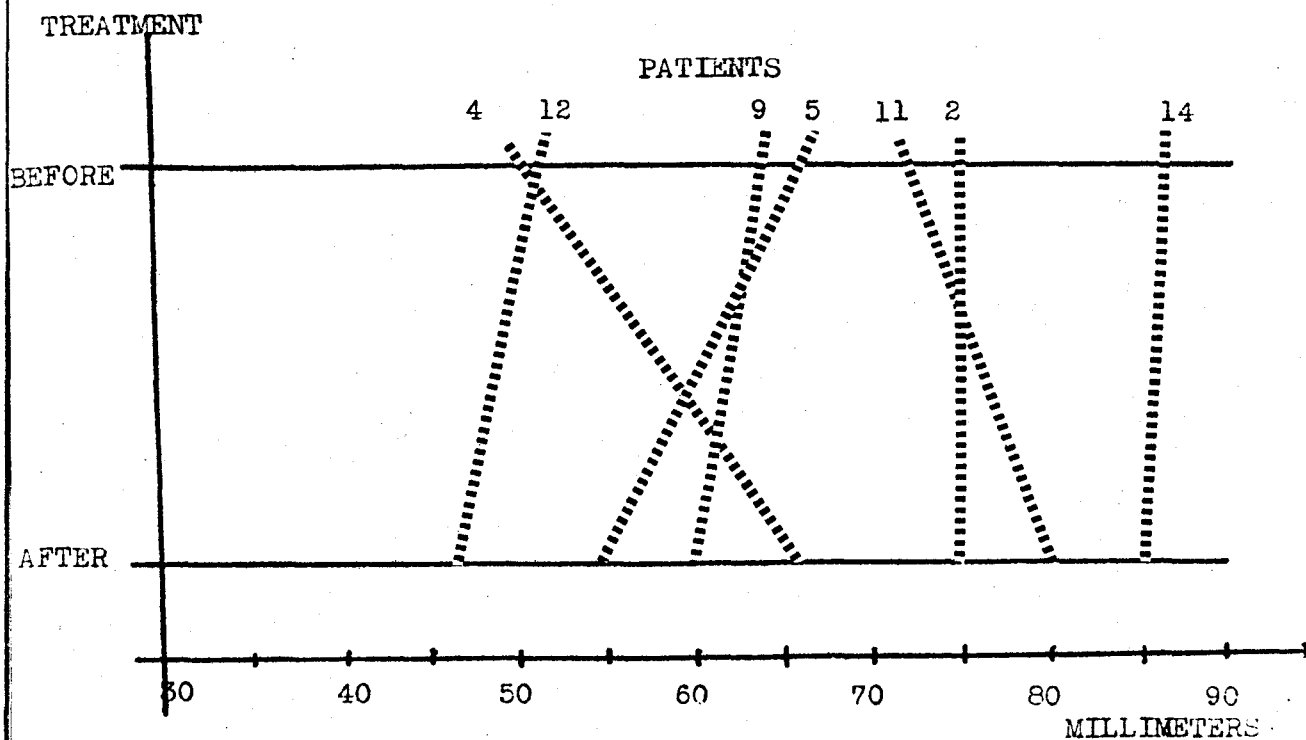


GRAPH OF PATIENTS X POSITIONS INTERACTION

FIGURE 33

THE LACK OF PARALLELISM OF THE DOTTED CONNECTING LINES INDICATES THE DIFFERENCE BETWEEN THE RELATIVE POSITIONS OF THE CROWNS AND ROOTS FROM THE MIDLINE IN PATIENTS TREATED WITH LIGHT FORCES

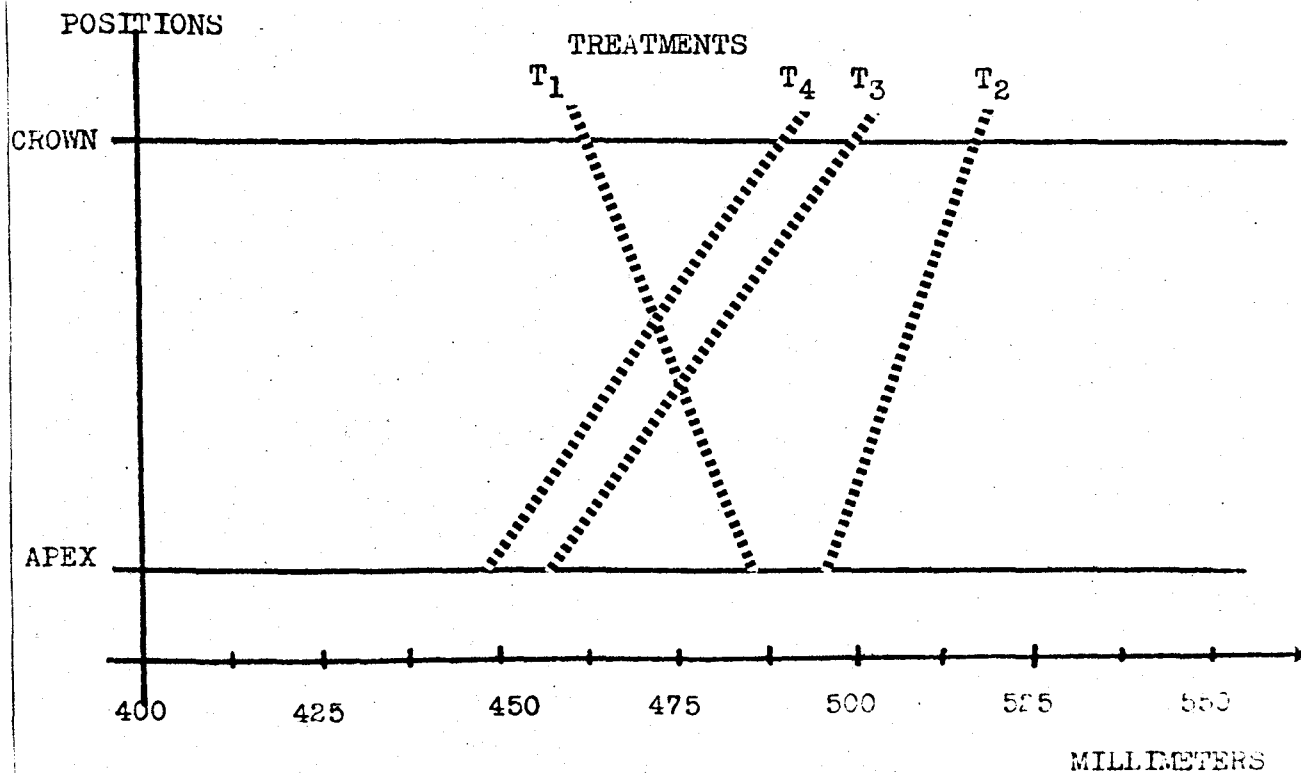
graph. It will be noted that the before treatment distances were altered considerably in the second, or anchorage, stage of treatment. The third and fourth stages of treatment show a general movement of the tooth forward and is explained on the basis of treatment objectives and forces employed in carrying out those objectives to achieve the desired result.



GRAPH OF PATIENTS X TREATMENT INTERACTION

FIGURE 34

THE LACK OF PARALLELISM OF THE DOTTED
CONNECTING LINES INDICATES THE DIFFER-
ENCE IN POSITION OF MANDIBULAR MOLAR
TEETH BETWEEN THE BEFORE AND AFTER
TREATMENT IN PATIENTS TREATED WITH
LIGHT FORCES



GRAPH OF TREATMENTS X POSITIONS INTERACTION

T₁ = Pre-Treatment

T₃ = Consolidation

T₂ = Anchorage

T₄ = Post-Treatment

FIGURE 35

THE DOTTED CONNECTING LINES SHOW
THE CHANGE OF BOTH CROWN AND APEX
IN PATIENTS TREATED WITH LIGHT FORCES
AT VARIOUS STAGES OF TREATMENT

CHAPTER V

DISCUSSION

The findings of this investigation will be discussed on the basis of different methods of treatment, evaluation, and mechanics responsible for the various types of tooth movement exhibited.

A. Patients treated with edgewise mechanics

The tooth movements exhibited by the mandibular first molars during the period of class II treatment which this study investigated were essentially the same according to both methods of evaluation (reference strips and visual appraisal). The consistent observation was a mesial movement in the crown and root areas in both extraction and non-extraction cases (Table III). Whether these movements occurred simultaneously in both areas or at different rates cannot be determined, but the fact is that over a period of twelve weeks there was a distinct widening of the periodontal membrane space on the distal root surface of both crown and root at the points measured. Stier (1962) in the initial phase of this study found that the prevalent type of tooth movement of the mandibular first molars was a distal tipping of the crowns of the teeth and a concomitant mesial movement of the roots with the point of rotation located in the cervical one-third

of the root. The mesial movement of the roots exceeding the distal movement of the crowns an average of 0.5 mm. The periodontal width in a tooth tipped distally at the crown would then be thinner than normal or compressed beyond detection on an intra-oral x-ray at the distal marginal area (point C, Figure 8). The periodontal width at the distal of the apex of the root would conversely be wider than normal as these roots are being moved in the opposite direction. When the mechanics are reversed as was done during this stage of treatment from a class III or distal force to a class II or mesial force, there was also a reversal in the direction of movement of the tooth. But this reversal took place mainly in the crown as evidenced by the evaluation of the periodontal width on the series of intra-oral roentgenograms taken at the end of twelve weeks of class II forces. This is not to say that there was no change in the root. As has already been indicated, the periodontal width at the apex of the root was also wider than normal, showing a continued forward movement. The only way to determine how much change the roots had undergone in position was by the measurements from the lateral headplates taken at the same time as the intra-oral x-rays. The data sheet (Figure 22) shows the distances measured in each instance.

Although all teeth moved mesially, there were different ratios of movements of crowns and roots (Table IV). The crowns and roots of two teeth (sides) in an extraction case moved

at the same rate, and one tooth (side) in a non-extraction case, or at least the measurements indicated an equal change in position. In five cases, the movement of the crowns of the teeth was greater than that of the roots. This mesial tipping occurred in two instances in extraction cases and three times in non-extraction cases. In fourteen instances, the mesial movement of the roots was greater than that of the crown, twelve in extraction cases and two in non-extraction cases.

The findings are graphically pointed out in the charts on interaction (Figures 22-26). The overall result of the treatment is well illustrated in Figure 28, the "Treatments x Position" graph. This indicated that there was a total movement of all crowns in both extraction and non-extraction cases of "before" and "after" treatment of from 375.0 mm to 307.5 mm, or a distance of 67.5 mm in a mesial direction. The roots moved during this same time in all patients a distance of from 330.0 mm to 249.5 mm, or 80.5 mm, also in a mesial direction. Therefore, the average movement of the crowns was 3.06 mm, while that of the root was 3.66 mm. The breakdown into extraction and non-extraction cases is given in Table III. The extraction cases showing considerably more mesial movement because of the break in continuity of the arch and consequent lessened resistance to tooth movements.

In eight cases, mechanics were employed to decrease

total arch length by advancing the mandibular molar teeth forward from their original positions. The most common technique used was the closed vertical loop. The loops are so fashioned that they lie one millimeter distal to the canine brackets. The loops are approximately ten millimeters in length on their distal leg and eight millimeters in length on the mesial leg. This elevated the buccal segment of the arch wire and depressed the anterior or incisal segment. The loop is bulbous at its base with the legs in contact before activation. The arch wire is activated by tying from the distal of the molar sheath to the tie-back loop bent into the arch wire about three millimeters anterior to the sheath. When exerting a mesial force on a tooth during space closure, it cannot at the same time be tipped distally, but it is possible to maintain its position of tip-back while advancing the tooth mesially by translation.

Where it is desired to maintain as much of the available space as possible, the tip-back bends in the lower 0.0215 x 0.028 inch arch wire are increased to effect a further distal inclination to the mandibular posterior teeth used as anchorage against the forward force exerted by the class II elastics. These types of mechanics were most often employed because of the need to conserve as much of the extraction site as possible. Salzman in his book on "Orthodontics-Practice and Technics" notes in a commentary on the Tweed Method that regardless of the skill

used in the mechanics of space closure following the extraction of teeth, there will always be a forward displacement to some extent of the buccal segments. He further makes the point that if incorrect mechanics are employed, it is possible to use up the entire extraction space and that unless the anchor molar teeth are first tipped back in both dental arches to gain anchorage advantage and vertical height, it is almost certain that the teeth in the buccal segments will be displaced mesially more than is necessary. Salzman also brings out the fact that there is no such thing as the so-called stationary anchorage, and that the entire mandibular denture is displaced mesially when the patient starts wearing class II elastics, including the mandibular incisors.

Huetnner and Whitman (1958) in their experiments on Macaque Rhesus monkeys found that tip-back bends did not prevent the mesial movement of posterior segments. They concluded that fixed anchorage is non-existent.

In this same experiment they also found that tip-back movements produced the most severe root resorption as well as compression and necrosis of the periodontal membrane, and that light to moderate forces appeared to produce the least amount of damage. Their histologic studies also showed areas of hemorrhage on the side of compression.

B. Patients treated with light wire mechanics

The tooth movements exhibited on intra-oral x-rays

during the period of space consolidation and class II mechanics which are under investigation in this study were in many cases difficult to evaluate because of the fact that a sufficient time had elapsed to allow the return of the periodontal membrane and cribriform plate to a normal appearance. The average treatment for all patients in this study was 21.5 months, with the longest period of 30 months and the shortest, 12 months; in extraction cases, the average treatment time was 26.8 months and 17.3 months for non-extraction cases. By comparing previous series of slides studied by Kemp (1961), it was possible to determine the "before" treatment positions of the teeth and compare with the "after" positions. Confirmation was also possible by checking the measurements of the lateral headplates taken at the same stages. The predominant change taking place in the periodontal width was a decrease at points A and B (mesial marginal and mesial apical areas), and a corresponding increase at points C and D (distal marginal and distal apical areas). In almost 50 per cent of the cases, this was interpreted as a mesial movement. The interaction of "Patients x Treatments" graphs (Figure 30) gives a remarkably clear picture of the several types of movements which occurred during this stage of treatment. For example, patients 1, 5, and 14, all show a mesial movement. Two other patients (Table VIII) also show a mesial movement, for a total of five patients in the whole series, three of whom were extraction cases and two non-

extraction cases. Both non-extraction cases were class II cases. Of three extraction cases, one was class I and two were class II. A mesial movement could be expected in a case requiring extractions because of the loss in arch continuity and therefore less resistant to tooth movements, but this is not the specific reason in these cases. When analyzed individually, we find in two extraction cases anchorage loss or mesial movement was part of the treatment plan because of the need to close vertical dimension and use up excess space from the extraction site. This is done in a class II case where the molar relationship is aided in correction by distal driving the upper molars and/or mesial driving the mandibular molars. In both instances, these mandibular first molar teeth were brought forward in a mesial bodily movement maintaining the level of the occlusal plane. In the third case, a class II case, because of the fact that the first molar teeth were tipped mesially into the site where second premolar teeth were missing, the need was to upright and bring the molars forward to close the space and to bring the roots forward a considerable distance for parallelism.

Another case also required excessive mesial movement of the molar teeth to bring the roots of second molars forward into the space of missing first molars. In this case, however, there was not mesial crown movement at the same time because the treatment objectives required that the molars be up-

righted and tipped distally to open the vertical dimension. This was accomplished with the help of headgear to the mandibular arch and triangular elastics as explained in Chapter III.

Patients 4 and 11, together with seven other patients, show a distal movement. Of these patients, four were treated extraction and five non-extraction. The five non-extraction cases were so treated because of the fact that the anchorage is not taxed during space consolidation and reduction of class II molar relationships if the sum total of intermaxillary and intramaxillary forces does not exceed five ounces, assuming angulated brackets are used to upright and/or tip-back the molar teeth and the total discrepancy between arch length and tooth size does not exceed 14 mm (Jarabak 1960). Three of the non-extraction cases were class I, requiring an average of fourteen months treatment time. The other two non-extraction cases were class II and required an average of twenty months treatment time. It is usually expected that the more discrepancy there is in the molar relationship, the more time it will take to correct the condition, and consequently the more the anchorage units will be taxed and subjected to mesial movement. There was little movement in two of these patients as shown by the almost vertical lines on the graph. Both cases were non-extraction cases using headgear to the mandibular arch to maintain the molars in position.

Of the four patients treated with extractions, one was in class I relation to start and treatment time was twenty-two months. The other three were class II cases with an average treatment time of twenty-four months.

It should be noted that while malocclusions fall into certain broad classifications there is a wide variation in severity within any of the classes. As a consequence of this, treatment time can vary from a few months to many years. Together with this must also be considered the facts of the level of patient cooperation in wearing headgear and elastics, being present at all scheduled appointments, ability to follow such instructions as not picking at bands or wires, keeping immaculate oral hygiene, reporting any loose bands or wires immediately, etc. The operator's technique are also subject to variation and mechanics employed by one orthodontist may not achieve the same result in the same period of time as in the hands of another orthodontist.

The measurements on this graph represent the combined total of the crowns and apices of each tooth before treatment on the upper line, and after treatment on the lower line. This gives an overall indication of the general movement of the teeth in each individual patient. A detailed analysis of the types of movements is given in Table VIII showing amounts of movement in extraction and non-extraction cases during total treatment

time.

To get a more specific picture of the changes taking place between crowns and roots, we can refer to Figure 33, the "Patients x Positions" graph. Here we see for instance in patients 1, 6, and 14, that the combined totals of the movement of the crowns is less than that of the roots, and in patients 8, 12, and 13, this total figure is more than that of the roots. In patients 7 and 9, these totals are about the same.

The "Treatments x Positions" graph (Figure 34) is a composite of all measurements taken during the whole course of treatment. T_1 represents the positions of all the tooth measurements combined. It will be noted that the total of all crown measurements places them in a position forward of the roots. This is obviously where the crowns are situated in most mouths in relation to the reference line drawn at the symphysis parallel to the mandibular plane. This is true even more so in malocclusions where the molar teeth are frequently tipped forward due to a shifting of the whole buccal segment, premature extraction, congenitally missing teeth, etc. T_2 gives the relative positions of the crowns and roots after a period of seventy-six days when the mandibular molar teeth were in most cases distally tipped and elevated during the anchorage preparation stage (Gantt 1960). Here graphic evidence is given that the crowns of the involved teeth have tipped distally a total of 58 mm, while the roots at

the same time have moved 8.5 mm in a distal direction. This is ample evidence of the effectiveness of a technique using light resilient arch wires and proper mechanics compounded to produce the desired result without sacrificing any of the extraction site. T_3 represents a period during the consolidation stage of treatment. Here we see a change of 18.5 mm in a mesial direction for the crowns, and 40.5 mm for the roots, an average 0.66 mm change for each tooth at the crown, and 1.4 mm at the root. This is a result of class II forces against the molar anchor units from such mechanics as class II elastics, intramaxillary elastics, and contraction loops. T_4 represents the final changes taking place from a period in space consolidation to the completion of treatment. As mentioned before, this stage varied from a few months to over two years in some cases, and yet the change is only 9.5 mm at the crown level and 8.0 mm at the roots. This averages out to 0.33 for the crown and 0.28 per root. We can see that the line T_4 is still distal to T_1 after treatment in spite of the fact that in several cases the mandibular molar teeth were purposely brought forward to close unneeded spaces, as in the case where first molars were missing and the second molar teeth were brought into the first molar space. Jarabak (1962, Lectures on Bio-Mechanics) states that the rate of tooth movement is determined by the magnitude of the applied force as related to the root surface area of the tooth upon which the force is acting,

providing the force is within limits to cause direct alveolar resorption. The type of tooth movement, on the other hand, is dictated by the mechanical principles in the design of the appliance. These principles are not synonymous with some specific type of wire or appliance but must be formulated and individualized by the orthodontist to suit the treatment objectives in a given case. The exerted force, however, and the amount of resiliency in an appliance depend very much on such factors as diameter of the wire, composition of the spring material, and the design of the spring itself. It is logical therefore that in order to achieve a certain type of tooth movement at an optimum rate of speed, one must apply the appropriate mechanical principles in combination with the proper amount of force.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. Summary

A. This investigation was a roentgenographic study of orthodontic tooth movement as exhibited by the mandibular first molar during (1) class II mechanics utilizing the edgewise mechanics as formulated by Tweed; a continuation of the work of Stier (1962); and (2) from space consolidation to completion of treatment utilizing light wire mechanics as formulated by Jarabak; a continuation of the work of Gantt (1960) and Kemp (1961).

The sample was comprised of two groups of patients being treated by the graduate students and the Loyola University School of Dentistry.

B. The types of tooth movements were determined by the interpretation of one hundred intra-oral roentgenograms taken during the treatment stages listed above. The amount of tooth movement in each case was derived from cephalometric measurements taken from lateral headplates.

Two methods were employed for the evaluation of the intra-oral roentgenograms. The first was based on the changes in the width of the periodontal space in four areas along the

root (mesial marginal, distal marginal, mesial apical, and distal apical areas) as recorded on paper reference strips, from which it was possible to determine the types of tooth movements which occurred in a mesio-distal direction during each stage of treatment. The second method of appraisal was a visual interpretation of the dimensional changes exhibited in both the periodontal width and the thickness of the cribriform plate. In addition, the overall positional change of the tooth as a result of orthodontic treatment was evaluated by this procedure. During both of these methods of appraisal, the intra-oral roentgenograms were magnified twenty times their original size utilizing a 35 mm slide projector. In the first method (recording the widths of the periodontal space on the reference strips), only one slide was projected at a time. In the second method, an entire series of slides in which each slide represented the same tooth at a different stage of treatment was projected simultaneously in order to obtain a composite picture and for ease of comparing the changes associated with each stage of treatment.

The amounts of tooth movement were computed from cephalometric measurements on lateral headplates. Through an analysis of these measurements, general and statistical, it was possible to determine the overall tooth movement which occurred during the entire period of observation.

C. The predominant types of tooth movements ob-

served during each state of treatment were as follows:

1. During the stage of class II mechanics in patients treated with edgewise appliances, the prevalent type of tooth movement observed was a mesial movement of the crowns on the average of 3.06 mm, while the roots moved an average of 3.36 mm in the same direction. These figures indicate that the overall type of tooth movement was a translation by tipping in both extraction and non-extraction cases. This study is being continued to show the effects of class II forces on the mandibular molar units to the completion of treatment.

2. A. A total summary of the entire treatment procedure during the various stages of patients treated with light forces shows Gantt (1960) found that during the stage of anchorage preparation the most common occurrences through the entire group of movements were:

1. Elevation of the tooth;
2. Distal tipping of the crown;
3. The axis of tipping occurred more commonly in the apical one-third of the root than it did in the middle one-third of the root.

The occurrence of distal tipping was both intentional and desirable and was created through the medium of the angulated brackets and triangular elastics. Cephalometric appraisal, as reported in the present study, gives evidence that the crowns of the teeth

under consideration during this stage were tipped distally a total of 58 mm, while the roots at the same time were moved 8-1/2 mm in a distal direction also.

B. Kemp (1961) found that during two periods of space consolidation mechanics:

1. The greatest variations in width of the periodontal space were found during the first few months when anchorage was being prepared which indicated that the maximum movement of the anchor teeth occurred during this treatment interval.
2. The periodontal space in most cases re-modeled to nearly its former width as seen prior to treatment indicating the mandibular molar anchor units were resisting the mesial forces exerted during the closure of space and therefore acting as excellent anchorage.

C.

1. In this study it was found that during the stage of consolidation and class II mechanics in light wire patients, the predominant (54 per cent) type of tooth movement observed was a mesial movement of the crowns

on the average of 1.28 mm, and 0.57 mm of the roots in extraction cases, and 1.04 mm for crowns and 0.66 mm for roots in non-extraction cases.

2. In 21 per cent of the cases the crowns and roots of the teeth were moved distally which meant a further distal tipping and elevation of the tooth from the previous stage of treatment.
3. Twenty-five per cent of the measurements showed no change at all, indicating that the mandibular molar teeth were being held in their desired position and were not affected adversely by the application of class II forces.

2. Conclusions

1. The use of a headholder in conjunction with a long cone on the x-ray machine and a fixed target distance of thirty inches reduces distortions on intra-oral roentgenograms and makes it possible to align the teeth in buccal segments with the central ray to such a degree that replicate roentgenograms are nearly of a duplicate nature.
2. The intra-oral roentgenograms taken during this investigation have shown clearly that the width of the periodontal

space and thickness of the cribriform plate were changed during orthodontic tooth movement and that these dimensional changes can be demonstrated radiographically on intra-oral roentgenograms. On the side of tension, the width of the periodontal space increased and on the pressure side, it decreased. During the process of tooth movement, the cribriform plate became thicker and more radiopaque on the tension side, and it disappeared on the side of pressure. These findings substantiate those of previous investigations reported in the literature.

3. The predominant tooth movement of the mandibular first molars during class II forces with the edgewise mechanism (utilizing tip-back bends in conjunction with "X" type orthospec class II elastics) was a mesial translation by tipping in which the average mesial root movement was greater than the mesial crown movement. Therefore tip-back bends did not prevent mesial movement of the posterior or segments and the anchorage did not remain stationary.

4. A. There is ample evidence from the data reported that a technique using light resilient arch wires and proper mechanics can compound forces in such a way as to produce a specific desired result.

B. This technique can be utilized to hold mandibular anchor units in place with little or no forward movement in extraction and non-extraction cases.

C. In cases where desired anchor units can be moved forward in a pure translatory movement where the crowns and roots move forward an equal distance thus maintaining the roots parallel and the tooth upright.

D. A distal tipping of anchor units is effected through the use of angulated brackets and triangularly placed elastics. This position can be maintained throughout the entire treatment procedure including consolidation of spaces and class II forces when they are in the range of light to intermediate forces not exceeding five ounces.

5. Another factor, not specifically studied in this investigation but obvious by its presence, was that there was no evidence of root resorption occurring during the treatment of the various patients.

6. The intra-oral roentgenograms also give evidence that the periodontal width remained small during treatment, an indication that apposition and resorption were going on at the same relative rate approaching a more physiological condition.

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APPENDICES

APPENDIX I

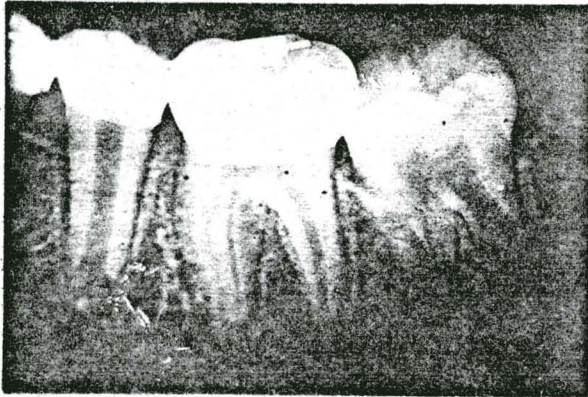
PATIENTS TREATED WITH EDGEWISE APPLIANCES



BEFORE TREATMENT



SEPARATION



LEVELING



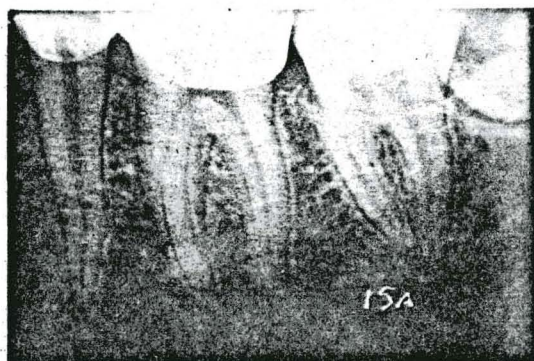
ANCHORAGE PREPARATION



CLASS II FORCES

APPENDIX II

PATIENTS TREATED WITH LIGHT FORCES SHOWING
DISTAL TIPPING AND ELEVATION



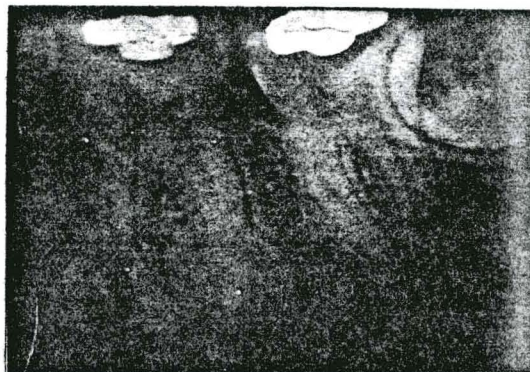
FIRST ARCH WIRE PLACED



DURING ANCHORAGE PREPARA-
TION



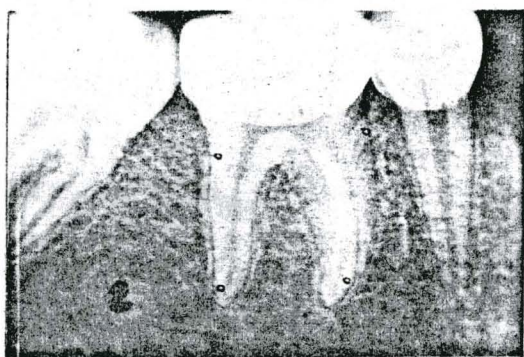
DURING CONSOLIDATION



AFTER TREATMENT

APPENDIX III

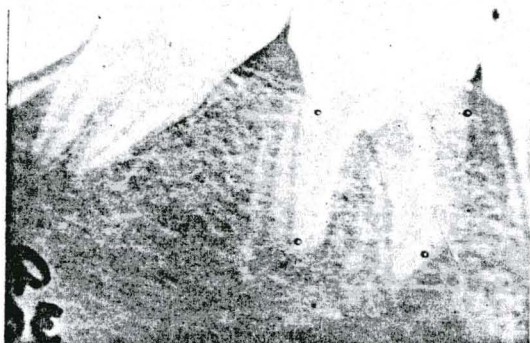
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MESIAL MOVEMENT OF CROWN AND ROOT



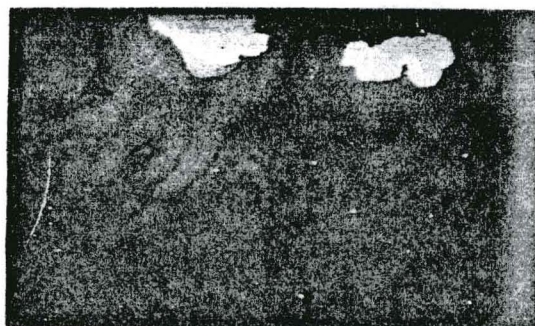
FIRST ARCH WIRES PLACED



DURING ANCHORAGE PREPARA-
TION



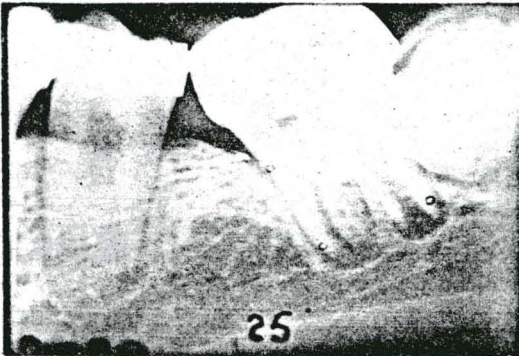
DURING CONSOLIDATION



AFTER TREATMENT

APPENDIX IV

PATIENTS TREATED WITH LIGHT FORCES SHOWING
ROOT PARALLELING AND UPRIGHTING OF
SECOND MOLAR INTO FIRST
MOLAR SPACE



FIRST ARCH WIRES PLACED



DURING ANCHORAGE PREPARATION



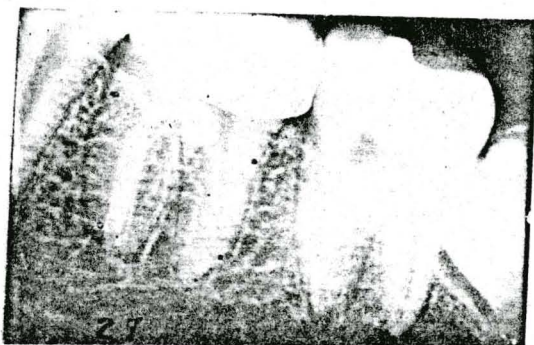
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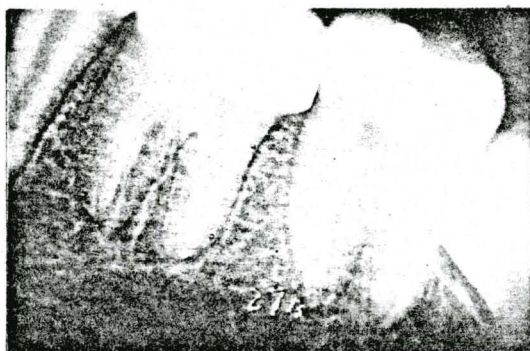
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APPENDIX V

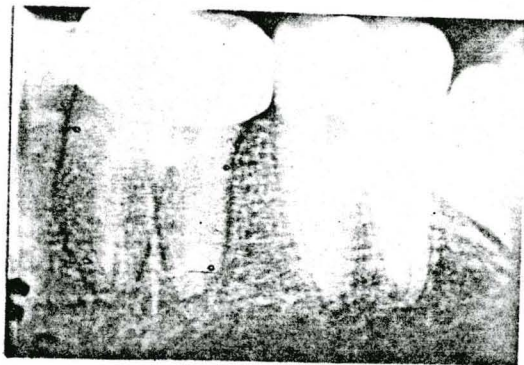
PATIENTS TREATED WITH LIGHT FORCES SHOWING
LITTLE OR NO CHANGE IN CRIBRIFORM PLATE



FIRST ARCH WIRES PLACED



DURING ANCHORAGE PREPARA-
TION



DURING CONSOLIDATION



AFTER TREATMENT

APPROVAL SHEET

The thesis submitted by Dr. R. E. Krvavica has been read and approved by members of the Departments of Anatomy and Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

5-15-63
DATE

Joseph R. Jarabak
Signature of Advisor